Bureau of Mines
Information Circular 7830

# BIBLIOGRAPHY OF ZIRCONIUM

## SUPPLEMENT TO INFORMATION CIRCULAR 7771

BY ELEANOR ABSHIRE

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United States Department of the Interior — 1958

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# INTRODUCTION

This bibliography is the second in a series that covers the current technical literature relating to the metallurgy of zirconium. The rapid advance in zirconium technology makes it mandatory that abstracts be prepared and compiled as soon as possible to have maximum value; therefore, the information in this volume is not arranged chronologically. As a service to research and production groups, succeeding bibliographies will be issued as new acquisitions accumulate in the Zirconium Information Center sponsored by the Department of the Navy, Bureau of Ships and the Bureau of Mines at the Bureau's Northwest Electrodevelopment Laboratory, Albany, Oreg.

The initial volume, Information Circular 7771, Bibliography of Zirconium, covering 969 abstracted reports and 645 United States and foreign patents, was published in April 1957.

The following reference sources have been used: ASM Metals Review; ASTIA Index; AEC (Oak Ridge) TID Index; Battelle Technical Review; Bibliography of Technical Reports; British Abstracts; Chemical Abstracts; Crerar Metal Abstracts; Current List of Medical Literature; Education Index; Engineering Index; Industrial Arts Index; Nuclear Science Abstracts; Quarterly Cumulative Index Medicus; and Readers Guide.

The material in this bibliography is divided into two sections - literature and patents. Each section is arranged alphabetically by authors. Secondary authors are cross-indexed. Titles of periodicals or organizations are used as the authors in anonymous references.

Special acknowledgment is due to Glen C. Ware, Chief, Branch of Technical Services, Bureau of Mines, Region I, for technical review of the manuscript and to the staff of the library at the Northwest Electrodevelopment Laboratory at Albany, Oreg.

# BIBLIOGRAPHY OF ZIRCONIUM[1]

## Supplement to Information Circular 7771

by

Eleanor Abshire[2]

## SELECTED ABBREVIATIONS

| | |
|---|---|
| Acta Chem. Scand. | Acta Chemica Scandinavica |
| Acta Cryst. | Acta Crystallographica |
| Acta Met. | Acta Metallurgica |
| Advances in Colloid Sci. | Advances in Colloid Science |
| Aeroprojects, Inc. | Aeroprojects, Incorporated |
| Am. Ceram. Soc. Bull. | American Ceramic Society Bulletin |
| Am. Foundryman | American Foundryman |
| Am. Inst. Chem. Eng. | American Institute of Chemical Engineering |
| AIME | American Institute of Mining and Metallurgical Engineers |
| Am. Jour. Clinical Pathology | American Journal of Clinical Pathology |
| Am. Machinist | American Machinist |
| Am. Metal Markets | American Metal Markets |
| Am. Mineral. | American Mineralogist |
| Am. Phys. Soc. Bull. | American Physical Society Bulletin |
| Am. Soc. Metals | American Society for Metals |
| ASTM | American Society for Testing Materials |
| Anal. Chim. Acta | Analytica Chimica Acta |
| Anal. Chem. | Analytical Chemistry |
| Anal. Chem. Manhattan Project | Analytical Chemistry of the Manhattan Project |
| Arch. Eisenhüttenw. | Archiv-für das Eisenhüttenwessen |
| Arch. Dermatol. Syphilol. | Archives of Dermatology and Syphilology |
| Astrophys. Jour. | Astrophysical Journal |
| Australasian Eng. | Australasian Engineer |
| Australian Chem. Inst., Jour. and Proc. | Australian Chemical Institute, Journal and Proceedings |
| Battelle Mem. Inst. | Battelle Memorial Institute |
| Battelle Tech. Rev. | Battelle Technical Review |
| British Intell. Objectives SubComm. | British Intelligence Objectives SubCommittee |
| British Jour. Ind. Med. | British Journal of Industrial Medicine |
| Bull. Chem. Soc. (Japan) | Bulletin, Chemical Society of Japan |
| Bull. Geol. Soc. Am. | Bulletin, Geological Society of America |
| Bull. Imp. Inst. | Bulletin, Imperial Institute |

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[1] Work on manuscript completed June 1956.

[2] Librarian, Bureau of Mines, Region I, Albany, Oreg., assisted by Helen L. Dreher and L. Jean Flora.

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|---|---|
| Canadian Chem. and Met. | Canadian Chemistry and Metallurgy |
| Canadian Chem. and Proc. Ind. | Canadian Chemistry and Process Industries |
| Canadian Jour. Phys. | Canadian Journal of Physics |
| Canadian Min. Jour. | Canadian Mining Journal |
| Canadian Min. and Met. Bull. | Canadian Mining and Metallurgical Bulletin |
| Ceram. Age | Ceramic Age |
| Ceram. Ind. | Ceramic Industry |
| Ceram. Soc. | Ceramic Society |
| Chem. Age | Chemical Age |
| Chem. Eng. | Chemical Engineering |
| Chem. Eng. and Min. Rev. | Chemical Engineering and Mining Review |
| Chem. Eng. News | Chemical Engineering News |
| Chem. Eng. Prog. | Chemical Engineering Progress |
| Chem. Met. Eng. | Chemical and Metallurgical Engineering |
| Chem. News | Chemical News |
| Chem. and Process Eng. | Chemical and Process Engineering |
| Chem. Rev. | Chemical Reviews |
| Chem. in Canada | Chemistry in Canada |
| Chem. and Ind. | Chemistry and Industry |
| Compt. rend. acad. sci. U. R. S. S. | Comptes rendus (Doklady) de l'académie des sciences de l'U. R. S. S. |
| Continental Met. and Chem. Eng. (Berlin) | Continental Metallurgical and Chemical Engineering (Berlin) |
| Current Sci. (India) | Current Science (India) |
| Dissertation Abs. | Dissertation Abstracts |
| Doklady Akad. Nauk S. S. S. R. | Doklady Akademi Nauk S. S. S. R. |
| Econ. Geol. | Economic Geology |
| Elec. Mfg. | Electrical Manufacturing |
| Eng. Min. Jour. | Engineering and Mining Journal |
| Federal Sci. Prog. | Federal Science Progress |
| FIAT | Field Information Technical Agency |
| Finska Kemistsamfundets Medd. | Finska Kemistsamfundets Meddelanden |
| Geochim. Cosmochim. Acta, London | Geochimica et Cosmochimica Acta, London |
| Geol. Mag. (London) | Geological Magazine (London) |
| Geol. Survey | Geological Survey |
| Heat Treat. and Forg. | Heat Treating and Forging |
| Idaho Bur. Mines and Geol. Miner. Res. Repts. | Idaho Bureau of Mines and Geology Minerals Resources Reports |
| Illinois Inst. Technol. | Illinois Institute of Technology |
| Indian and Eastern Eng. | Indian and Eastern Engineering |
| Indian Jour. Phys. | Indian Journal of Physics |
| Ind. Canada | Industrial Canada |
| Ind. Chem. | Industrial Chemist |
| Ind. Eng. Chem. | Industrial and Engineering Chemistry |
| Inst. Min. and Met. | Institute of Mining and Metallurgy |
| Iowa State Coll. Jour. of Sci. | Iowa State College Journal of Science |
| Jet Propulsion Lab. | Jet Propulsion Laboratory |
| Jour. Am. Ceram. Soc. | Journal, American Ceramic Society |
| Jour. Am. Chem. Soc. | Journal, American Chemical Society |
| Jour. Am. Leather Chemists' Assoc. | Journal, American Leather Chemists' Association |
| Jour. Appl Chem. (U. S. S. R.) | Journal of Applied Chemistry (U. S. S. R.) |
| Jour. Appl. Phys. | Journal of Applied Physics |
| Jour. Biol. Chem. | Journal of Biological Chemistry |
| Jour. British Interplanetary Soc. | Journal, British Interplanetary Society |

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|---|---|
| Jour. Canadian Ceram. Soc. | Journal, Canadian Ceramic Society |
| Jour. Chem. Phys. | Journal of Chemical Physics |
| Jour. Colloid Sci. | Journal of Colloid Science |
| Jour. Electrochem. Soc. | Journal, Electrochemical Society |
| Jour. Franklin Inst. | Journal, Franklin Institute |
| Jour. Indian Chem. Soc. | Journal, Indian Chemical Society |
| Jour. Indian Inst. Sci. | Journal, Indian Institute of Science |
| Jour. Ind. and Eng. Chem. | Journal of Industrial and Engineering Chemistry |
| Jour. Inst. Fuel | Journal, Institute of Fuel |
| Jour. Inst. Metals | Journal, Institute of Metals |
| Jour. Iron and Steel Inst. (London) | Journal, Iron and Steel Institute (London) |
| Jour. Lab. Clin. Med. | Journal of Laboratory and Clinical Medicine |
| Jour. Madras Univ. | Journal, Madras University |
| Jour. Maine Med. Assoc. | Journal, Maine Medical Association |
| Jour. Metals | Journal of Metals |
| Jour. Neurosurgery | Journal of Neurosurgery |
| Jour. Optical Soc. America | Journal, Optical Society of America |
| Jour. Organic Chem. | Journal of Organic Chemistry |
| Jour. Pharmacol. and Exper. Therap. | Journal of Pharmacology and Experimental Therapeutics |
| Jour. Phys. Chem. | Journal of Physical Chemistry |
| Jour. Phys. and Colloid Chem. | Journal of Physical and Colloid Chemistry |
| Jour. Phys. Soc., Japan | Journal of Physical Society of Japan |
| Jour. Research, Nat. Bureau of Standards | Journal of Research, National Bureau of Standards |
| Jour. Sci. Ind. Research (India) | Journal of Scientific and Industrial Research (India) |
| Jour. Soc. Chem. Ind. | Journal, Society of Chemical Industry |
| Jour. Soc. Glass Technol. | Journal, Society of Glass Technology |
| Jour. Soc. Leather Trades' Chemists | Journal, Society of Leather Trades' Chemists |
| Jour. Soc. Motion Picture and Television Eng. | Journal, Society of Motion Picture and Television Engineers |
| Kolloid-Ztschr. | Kolloid-Zeitschrift |
| Kgl. Danske Videnskab. Selskab, Mat. fys. Medd. | Kongelige Danske Videnskabernes Selskab, Mathematisk-fysiske Maddelelser |
| Los Alamos Sci. Lab. | Los Alamos Science Laboratory |
| Metal Ind. | Metal Industry |
| Metall u. Erz | Zeitschrift für Erzbergbau und Metallhuttenwesen |
| Met. Chem. Eng. | Metallurgical and Chemical Engineering |
| Metals Rev. | Metals Review |
| Mineral. Mag. and Jour. Mineral. Soc. | Mineralogical Magazine and Journal of the Mineralogical Society |
| Mines Mag. | Mines Magazine (Colorado School of Mines) |
| Min. and Contract. Rev. | Mining and Contracting Review |
| Min. Eng. | Mining Engineering |
| Min. Jour. | Mining Journal |
| Min. Mag. | Mining Magazine |
| Min. World | Mining World |
| Murex Rev. | Murex Review |
| Nat. Acad. Sci. | National Academy of Science |
| Nat. Advisory Comm. of Aeronau. | National Advisory Commission of Aeronautics |
| Nat. Bureau of Standards Circ. | National Bureau of Standards Circular |
| Nat. Research Corp. | National Research Corporation |

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|---|---|
| Nat. Safety News | National Safety News |
| New England Jour. Med. | New England Journal of Medicine |
| N. J. Ceram. Res. Sta. | New Jersey Ceramic Research Station |
| N. Y. State Coll. Ceram. | New York State College of Ceramics |
| Nova Acta Regiae Soc. Sci. Upsaliensis | Nova Acta Regiae Societatis Scientiarum Upsaliensis |
| Off. Digest, Federation Paint and Varnish Production Clubs | Official Digest of Federation of Paint and Varnish Production Clubs |
| Philips Tech. Rev. | Philips Technical Review |
| Phys. Rev. | Physical Review |
| Physiol. Rev. | Physiological Reviews |
| Plansee Proc. | Plansee Proceedings |
| Popular Sci. | Popular Science |
| Powder Met. Bull. | Powder Metallurgy Bulletin |
| Proc. Am. Acad. Arts and Sci. | Proceedings, American Academy of Arts and Sciences |
| Proc. Cambridge Phil. Soc. (England) | Proceedings, Cambridge Philosophical Society (England) |
| Proc. Fifth Summer Conf. on Spectroscopy and Its Applications | Proceedings, Fifth Summer Conference on Spectroscopy and Its Applications |
| Proc. Indian Acad. of Sci. | Proceedings, Indian Academy of Sciences |
| Proc. Internat. Cong. Pure and Appl. Chem. | Proceedings, International Congress of Pure and Applied Chemistry |
| Proc. Phys. Soc. (London) | Proceedings, Physical Society (London) |
| Proc. Physico-Math. Soc. (Japan) | Proceedings, Physico-Mathematical Society (Japan) |
| Proc. Roy. Acad. Sci. (Amsterdam) | Proceedings, Royal Academy of Sciences (Amsterdam) |
| Proc. Roy. Soc. (London) | Proceedings, Royal Society (London) |
| Proc. Soc. Exptl. Biol. Med. | Proceedings, Society for Experimental Biology and Medicine |
| Prod. Eng. | Product Engineering |
| Record of Chem. Prog. | Record of Chemical Progress |
| Rec. trav. chim. | Recueil des travaux chimiques des Pay-Bas |
| Refractories Jour. | Refractories Journal |
| Rensselaer Polytechnic Inst. | Rensselaer Polytechnic Institute |
| Rev. Sci. Instruments | Review of Scientific Instruments |
| Royal Aircraft Estab. | Royal Aircraft Establishment |
| Safety Eng. | Safety Engineer |
| Sci. and Culture | Science and Culture |
| Sci. Digest | Science Digest |
| Sci. Am. | Scientific American |
| Sci. Papers, Nat. Bureau Standards | Scientific Papers of National Bureau of Standards |
| Sci. Papers Inst. Phys. Chem. Research (Tokyo) | Scientific Papers of Institute of Physical and Chemical Research (Tokyo) |
| Sci. Repts. Tohoku Imp. Univ. | Scientific Reports Tohoku Imperial University |
| Sheet Metal Ind. | Sheet Metal Industries |
| Soil Sci. | Soil Science |
| Soil Sci. Soc. Am., Proc. | Soil Science Soc. of America, Proceedings |
| South African Min. and Eng. Jour. | South African Mining and Engineering Journal |
| Spectrochim. Acta | Spectrochimica Acta |
| Surg. Gynecol. Obstet. | Surgery, Gynecology and Obstetrics |
| Sylvania Elec. Prod., Inc. | Sylvania Electric Products, Inc. |
| Tech. Phys. U. S. S. R. | Technical Physics of U. S. S. R. |

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|---|---|
| Technol. Repts. Osaka Univ. | Technology Reports of Osaka University |
| Technol. Repts. Tohoku Univ. | Technology Reports of Tohoku University |
| Trans. AIME | Transactions, American Institute of Mining and Metallurgical Engineers |
| Trans. ASME | Transactions, American Society for Mechanical Engineers |
| Trans. British Ceram. Soc. | Transactions, British Ceramic Society |
| Trans. Ceram. Soc. | Transactions, Ceramic Society |
| Trans. Electrochem. Soc. | Transactions, Electrochemical Society |
| Trans. Eng. Ceram. Soc. | Transactions, English Ceramic Society |
| Trans. Faraday Soc. | Transactions, Faraday Society |
| Trans. Indian Inst. Metals | Transactions, Indian Institute of Metals |
| Trans. Roy. Soc. Canada | Transactions, Royal Society of Canada |
| Virginia Jour. Sci. | Virginia Journal of Science |
| Welding Jour. | Welding Journal |
| Western Ind. | Western Industry |
| Zhur. Fiz. Khimii | Zhurnal Fizicheskoi Khimii |

## JOURNAL REFERENCES

### A

1. **ABOU-EL-AZM, A. E. M.** Study of the Reaction Rates Between Silica, Alumina, Mullite, Zirconia, and Other Oxides at Various Temperatures. Jour. Soc. Glass Technol., vol. 37, No. 179, December 1953, pp. 269-301.

Additional work on reactions between silica and one or more metallic oxides was carried out with a view to investigating how the reaction rates are modified by: (1) Introduction of lime as CaO and as $CaCO_3$, (2) the presence of alumina or zirconia, (3) the particle size of the silica, and (4) the forms in which the silica is introduced. Reaction rates between alumina, mullite, or zirconia and one or more of the other metallic oxides were also investigated by the X-ray diffraction method. The results obtained showed that the addition of alumina or zirconia to a silica-soda mixture decreases the reaction rates in the initial stages of firing, but after a certain period of firing at 1,400° the reaction rates are higher; zirconia reacts with the other metallic oxides more slowly than mullite or silica and also reacts more slowly than alumina, except with the alkalis or boric oxide. The various alkali-metal oxides and alkaline earths, arranged in decreasing order of their reaction rates with silica, alumina, mullite, or zirconia, can be placed as follows: $K_2O$, $Na_2O$, $Li_2O$ and BaO, CaO, ZnO, and MgO, respectively, when they are present in molecularly equivalent quantities. The progress of the reactions between silica, alumina, mullite, or zirconia and 1 or more of the other oxides can be represented by 1 or other of the following 2 equations, depending upon the composition and temperature of firing:

$$R\left[1-\left(\frac{m}{M}\right)1/3\right]\log\alpha = \log t + \text{constant}, \quad (1)$$

and

$$1-\left(\frac{m}{M}\right)1/3 = \text{constant} \times t \; . \; . \; . \quad (2)$$

In the reactions which could be represented by equation (1), the value of the factor alpha decreased with increase of the reaction rates.

2. **ABRAMS, R., SEIBERT, H. C., POTTS, A. M., LOHR, W., AND POSTEL, S.** Metabolism of Inhaled Fission Product Aerosols. Argonne Nat. Lab., MDDC-248, May 24, 1946, 109 pp.

This paper deals with the metabolism of airborne fission products in rats. Four different isotopes were selected for their long lives and as representatives of the various chemical species occurring in fission. They were $Sr^{89}$ (55 days), $Zr^{95}$ (65 days), $Y^{91}$ (57 days), and $Ce^{144}$ (275 days). Aerosols of these materials were produced by atomizing aqueous solutions and by burning dried residues in a carbon arc. The three elements yttrium, zirconium, and cerium may be grouped insofar as they differ from strontium. All were eliminated from the lung much more slowly than was strontium. Thus the times required for 90-percent elimination were: $Y^{91}$ (12 days), $Zr^{95}$ (25 days), and $Ce^{144}$ (45 days). In all cases, the skeleton was the major site of deposition and eventually contained 15 to 30 percent of the initial lung deposit. In no case, in periods ranging up to 200 days, did the total radiation dose to the bone exceed that to the lung, as it did within 12 hours with strontium. With all three elements, the probability of radiation damage to the lung is great.

3. **ACCOUNTIUS, O. E., BLACK, D. G., DRYDEN, C. E., FINNEY, B. C., GRUBER, B. A., JUREVIC, W. G., McDONOUGH, R., PLOCK, L. F., STEPHAN, D. J., WOODRUFF, S. A., AND CAMPBELL, I. E.** Zirconium Pilot-Plant Research and Development. Progress Report. Battelle Mem. Inst., BMI-530, Sept. 20, 1951, 13 pp.

This report summarizes the progress on zirconium pilot-plant research. The vaporizer condenser was used to condense 430 lb. of zirconium iodide made in the third iodination run. No salt leakage occurred. Vigorous gasification occurred during the last stages of dehydration, where heat was applied. This reaction with water did not hinder subsequent iodination. A third deposition run was made using both single and multiple filaments. With the multiple-filament configuration of 4 hairpins, deposition proceeded at a rate of 0.8 lb. per hour for 2-1/2 hours, when a burnout occurred. The pressure in the system was high (5 mm.), indicating plugging. On switching to the single filament, the pressure gradually rose to 30 mm., and no metal could be deposited. By inspecting the units after shutdown, a plug was found at the entrance to each iodine condenser. The iodide condensers were in good condition. It is planned to overcome this plugging condition by modifying the coolant flows and raising the temperature of the connecting line between the iodide and iodine condensers. Laboratory experiments on repeated sublimations of $ZrI_4$ are completed. When $ZrI_4$ is prepared in "in situ" as a duplication of plant runs, the high-boiling fractions are reduced. The small quantity of grayish residue is probably an impurity in the zirconium sponge.

ACHERMAN, W. L. See abs. 298, 299.

ADAIR, R. K. See abs. 88.

ADAMS, A. M. See abs. 537.

4. ADAMS, M. Thermal Conductivity: III. Prolate Spheroidal Envelope Method. Data for $Al_2O_3$, BeO, MgO, $ThO_2$ and $ZrO_2$. Jour. Am. Ceram. Soc., vol. 37, No. 2:2, February 1954, pp. 74-79.

An absolute method of determining the thermal conductivity of refractory materials is described. This investigation confines itself to the steady state, where the temperature at any given point in the material is independent of time. The variation of conductivity with temperature is shown for alumina, magnesia, zirconia, beryllia, thoria, and insulating firebrick B and W K-28. The results of previous studies are compared with those of this investigation.

See also abs. 601.

5. ADAMS, M., AND LOEB, A. L. Thermal Conductivity: II. Development of a Thermal Conductivity Expression for the Special Case of Prolate Spheroids. Jour. Am. Ceram. Soc., vol. 37, No. 2:1, February 1954, pp. 73-74.

A straightforward derivation of the heat-flow equation for a prolate spheroid is given. In its simplest form the expression is thermal conductivity equals body factor (determined for the prolate spheroidal vessel) times power divided by temperature drop. The geometry of the prolate spheroid is reflected in a detailed expression for the body factor.

6. ADENSTEDT, H. K. Physical, Thermal, and Electrical Properties of Hafnium and High-Purity Zirconium. Am. Soc. Metals, vol. 44, 1953, pp. 949-967.

The following physical, thermal, and electrical properties of hafnium metal (99+ percent) and high-purity, hafnium-free zirconium metal (99.9+ percent) were determined: Density at 68° F. (20° C.), melting point, modulus of elasticity, thermoelectric force relative to platinum between room temperature and approximately 1,830° F. (1,000° C.), electrical resistivity and thermal expansion between -294° F. (-183° C.) and approximately 1,830° F. (1,000° C.), and the mean specific heat between 80° F. (25° C.) and 212° F. (100° C.). Samples were prepared from as-deposited iodide crystal bars, cold-swaged rods, cold-swaged and annealed rods, annealed sheet, and wire. The condition of the samples influenced some of the properties (electrical resistivity, thermal expansion, transformation range). This is due partly to the hexagonal structure and preferred orientation of the samples and partly to contamination of the metal during processing (hafnium). Evaluation of the literature shows the following: The new observed melting point of hafnium is lower and the new modulus of elasticity of zirconium is higher than found before. The modulus of elasticity, thermoelectric force, and thermal expansion of hafnium could not be compared, since these properties were not known before. The rest of the values were found to be in satisfactory agreement with the literature.

7. **AFAF, M.** Band-Spectrum of ZrO. Proc. Phys. Soc. (London), vol. 63, No. 10-A, 1950, pp. 1156-1170.

The spectrum of ZrO has been photographed in the ultraviolet, the visible, and the infrared from arcs running under special conditions. This has made possible the identification of 3 new systems in the ultraviolet, as well as 2 less conspicuous ones in the infrared. It has also made it possible to extend the blue-system alpha of ZrO.

8. ___. Band Systems of Zirconium Oxide (ZrO) in the Ultra-Violet. Nature, vol. 164, No. 4174, Oct. 29, 1949, pp. 752-753.

Three systems of zirconium oxide were observed in the ultraviolet. The zirconium oxide spectrum was photographed in the region 2930-6700 A, free of lines, with identification of the real bandbeads possible. Details are given.

9. ___. Bands of ZrF. Proc. Phys. Soc. (London), vol. 63, No. 5-A, 1950, pp. 544-545.

On a large Littrow spectrograph, the author photographed bands believed to be emitted by ZrF vapor in a low-voltage arc between copper electrodes. The ZrF (zirconium monofluoride) was produced by putting $ZrF_4$ (with impurities of KF and $H_2O$) in the lower anode cup and controlling the voltage to maintain the temperature above the melting but below the ignition temperature of $ZrF_4$. An attempt to vaporize and excite ZrF in a constricted capillary of a high-current-discharge tube of the type used by Pearse and Gaydon yielded only bands due to SiF and SiO.

10. ___. Singlet System B of ZrO. Proc. Phys. Soc. (London), vol. 63, A, 1950, pp. 674-675.

A singlet system has been identified for ZrO, of which the lambda band head is the (0,0) band. This system has been designated as system B. Nine band heads were observed for this system. The record of the various band heads, as measured by the author in the region of the bands of system B, along with the analysis, is given.

11. **ALLEN, N. P., AND CARRINGTON, W. E.** Exploratory Creep Tests on Metals of High Melting Point. Jour. Inst. Metals, vol. 82, July 1954, pp. 525-533.

The strength at 1,000° C. of a number of metals in their purest available form, with melting points above that of iron, was assessed by compression creep tests in vacuo, the criterion being the stress needed to give 1-percent creep strain in 24 hours. Titanium, zirconium, vanadium, niobium, tantalum, chromium, molybdenum, tungsten, platinum, palladium, rhodium, iridium, iron, cobalt, nickel, and certain sintered carbides were tested. When high-temperature strength was plotted against atomic number, a periodicity similar to that given by the melting points and elastic constants of the metals was obtained. The materials tested are discussed in the light of their usefulness for high-temperature service.

12. **ALTMAN, H. W., RUBIN, T., AND JOHNSTON, H. L.** Coefficient of Thermal Expansion of Solids at Low Temperature. III. Thermal Expansion of Pure Metals, With the Data for Aluminum, Nickel, Titanium, and Zirconium. Ohio State Univ., AD-26970, TR-264-27, Feb. 10, 1954, 10 pp.

Thermal expansion coefficients have been determined in the interval 20° to 300° K. for the 4 pure metals, aluminum, nickel, titanium, and zirconium. The apparatus and experimental technique are the same as described for the measurements with copper.

13. **ALTWICKER, H.** Ternary Magnesium Alloys Containing Zirconium. Wright-Patterson Air Force Base, ATI-22439, F-TR-1194-ND, January 1949, 21 pp.

German research and accomplishments in magnesium-zirconium alloys containing appreciable amounts of other metals are described. The metals employed for alloying were aluminum, antimony, beryllium, cerium, manganese, nickel, silicon, silver, thorium, and zinc. These are divided into two groups, those that improve the properties of magnesium-zirconium systems and those that have deleterious effects. It was determined that aluminum, antimony, manganese, silicon and tin would not alloy successfully with magnesium-zirconium systems, nor would beryllium in the presence of aluminum. On the other hand, beryllium, in the presence of cadmium and zinc, cadmium, cerium, thorium, silver, or zinc improve magnesium-zirconium system. Compositions and physical properties of the principal German magnesium-zirconium alloys are listed and presented in curves, tables, and photographs.

14. ALTWICKER, H. Zirconium in Magnesium. Wright-Patterson Air Force Base, ATI-27205, F-TR-1185-ND, August 1948, 19 pp.

The results of research and development in magnesium-zirconium alloy systems, which were accomplished at I. G. Farbenindustrie, are presented. Owing to the relatively poor solubility of zirconium in magnesium, a number of difficulties were experienced in the initial stages. The two methods employed were: (1) Use of metallic zirconium; and (2) introduction of zirconium containing salts into the melt. The results and statistics relative to grain refinement in the various compositions are given in the text, which is accompanied by tables and figures for castings, sheets, extrusions, and welded specimens.

15. AMERICAN MACHINIST. Zirconium: Summary of Current Shop Practice. Vol. 98, No. 8, Apr. 12, 1954, pp. 199-202.

Data are given on heating, hot working, ingot forging, scale removal, extrusions, tube, rod and wire fabrication, cold working and forming, and annealing and machining of zirconium and zirconium alloys.

16. AMERICAN METAL MARKET. Nuclear Work Leads to Sudden Demand for Zirconium. Mar. 7, 1953, pp. 1, 12.

A news item on the growing demands for zirconium and the role it will play in building the first atomic engine for submarine propulsion.

17. AMPT, G. A. Determination of Zirconium. Australian Chem. Inst., Jour. and Proc., vol. 2, No. 12, December 1935, pp. 321-334.

This report briefly recounts the history, occurrence, uses and reactions of zirconium, attack by various fluxes, and determination by the phosphate and by the cupferron methods. Gives detailed description of the analysis of zircon.

AMSTEL, J. J. A. P. van. See van AMSTEL, J. J. A. P.

ANDERSON, C. H. See abs. 245.

18. ANDERSON, C. T., HAYES, E. T., ROBERSON, A. H., AND KROLL, W. J. Preliminary Survey of Zirconium Alloys. Bureau of Mines Rept. of Investigations 4658, 1950, 48 pp.

This report covers the preliminary study of about 25 zirconium-rich alloy systems with respect to preparation, fabrication, tensile properties, metallographic structures, constitution, and heat resistance.

ANDERSON, D. See abs. 246.

ANDERSON, J. S. See abs. 614, 813.

ANDREW, K. F. See abs. 316, 317, 318, 319, 320.

ANSEL, G. See abs. 210.

AMTSELEVICH, N. S. See abs. 39.

19. APPLIED RESEARCH LABORATORY. Establishment of Quantitative Spectrographic

Methods of Analysis of Various Raw and Finished Ceramic Materials. 3d Quart. Progress Rept. for Jan. 1, 1947, NP-1936, April 1947, 21 pp.

This report continues the investigation of the application of spectrographic methods of analysis to alkaline earth titanates and zirconates and to other related materials used in manufacturing ceramic bodies. The progress reported is good. These standards have been established for spectrochemical analysis of commercial strontium titanates. The report deals with the tentative methods for establishing standards and for routine analysis of titanates. These methods of spectrochemical analysis show fairly good reproducibility.

ARCH, A. See abs. 838.

20. ARMAGNAC, A. P. Atomic Piles and Sparking Flints Put Zirconium to Work. Popular Sci., vol. 158, April 1951, pp. 156-159.

A new process yields a once-rare metal by the ton, permitting large-scale application of its valuable properties.

21. ARMOUR RESEARCH FOUNDATION. Development of Ceramic Materials of High Electrical Conductivity. Quart. Rept. 2, NP-3240, Apr. 15, 1951, 11 pp.

Yellow, metallic crystals of sodium-tungsten bronze are formed through the reduction of sodium tungstate with a combination of tungstic oxide and tungsten under an inert atmosphere at temperatures between 850° and 900° C. Similar reactions with zirconium and zirconyl tungstate at higher temperatures (1,200° C.) result in the formation of blue materials. The blue products approach the compositions expected for zirconium and zirconyl-tungsten bronze, which are represented by the formulas $Zr(WO_3)_4$ and $ZrO(WO_3)_2$, respectively. X-ray-diffraction analysis indicates that they are compounds and not fused mixtures of the starting materials.

22. ___. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 1, Jan. 1 - Mar. 1, 1951; AECU-1223, Mar. 3, 1951, 10 pp.

This is the first report in a series to be issued on the investigation of the following systems: Zirconium-tin; zirconium-molybdenum; zirconium-copper; zirconium-wolfram; zirconium-chromium; zirconium-silicon; zirconium-aluminum; zirconium-magnesium. A brief analysis of the possible phase relationships involved was made, the experimental techniques for alloy preparation and annealing treatments are discussed, and results of preliminary experiments are presented.

23. ___. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 2, Mar. 1 - May 1, 1951; COO-30, May 14, 1951, 14 pp.

During this period work was continued on the zirconium-tin system, and much of the melting program for the zirconium-molybdenum and zirconium-copper systems was completed. A few experimental zirconium-tungsten melts were made. A large number of annealing treatments were completed on zirconium-tin alloys containing up to 20 percent tin, and micrographic analysis of these specimens is nearly complete. A number of melting-range determinations was made in this system by the incipient melting technique. X-ray investigations of several alloys were begun.

24. ___. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 3, May 1 - July 1, 1951; COO-31, July 10, 1951, 18 pp.

The melting programs for the binary systems of zirconium with tin, molybdenum, copper, chromium, and silicon are complete and the melting of zirconium-aluminum alloys is nearing completion. Experimental trials have revealed a melting technique for zirconium-tungsten alloys that appears to eliminate unmelted tungsten. Limited melting trials with zirconium-magnesium alloys have shown that special techniques will probably have to be developed for their manufacture. Microstructural analysis of heat-treated alloys has yielded a good outline of the zirconium-tin system in the 0- to 46-percent tin range, and corroborative work, utilizing other techniques, is under way. The systems of zirconium with molybdenum, copper, chromium, silicon, and aluminum have been surveyed by the examination of as-cast alloys. The phases present and the general phase relationships in each of these systems are outlined. Heat treatments to determine precisely the phase relationships in the zirconium-rich regions of the zirconium-molybdenum, zirconium-copper, and zirconium-chromium systems have been started and are in various stages of completion.

25. ARMOUR RESEARCH FUNDATION. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 4, July 1 - Sept. 1, 1951; COO-32, Sept. 18, 1951, 17 pp.

The status of the systems of zirconium with the elements tin, molybdenum, copper, tungsten, chromium, silicon, aluminum, and magnesium is described.

26. ___. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 5, Sept. 1 - Nov. 1, 1951; COO-81, Nov. 27, 1951, 26 pp.

The status of the systems of zirconium with the elements tin, molybdenum, copper, tungsten, chromium, silicon, aluminum, and magnesium is described.

27. ___. Phase Diagrams of Zirconium-Base Binary Alloys: A Study of the Systems of Zirconium With Tin, Molybdenum, Copper, Wolfram, Chromium, Silicon, Aluminum, and Magnesium. Final Rept., Jan. 1, 1951 - Mar. 31, 1952; COO-89, Apr. 14, 1952, 173 pp.

High-purity alloys of the various systems were arc-melted, annealed, and subjected to thermal analysis under special protective conditions. Phase diagrams were determined for the systems zirconium-tin, zirconium-molybdenum, zirconium-copper, zirconium-wolfram (tungsten), zirconium-chromium, zirconium-silicon, and zirconium-aluminum, except zirconium-magnesium.

28. ___. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 7, Apr. 1 - June 30, 1952 (The Zirconium-Oxygen System); COO-98, June 30, 1952, 9 pp.

Experimental techniques for the preparation of alloys and their annealing are discussed. The results of preliminary experiments in the phase relationships in the zirconium-oxygen binary system up to 50 atomic percent oxygen are presented.

29. ___. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 8, July 1 - Sept. 30, 1952 (The Zirconium-Oxygen Systems); COO-100, Sept. 30, 1952, 7 pp.

This report covers the progress in determining the zirconium-oxygen binary phase diagram from 0-50 atomic percent. Experimental techniques employed for preparing alloys are discussed. Alternative diagram types based on an as-cast survey of alloys are presented. The allotropy of $ZrCr_2$ is also discussed.

30. ___. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 9, Oct. 1 - Dec. 31, 1952 (The Zirconium-Oxygen System); COO-123, Dec. 31, 1952, 4 pp.

This report covers progress in determining the zirconium-oxygen binary phase diagram from 0 to 50 atomic percent. Alloy preparation is discussed, and a schedule of isothermal annealing treatments presented. Chemical analysis data are given.

31. ___. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 10, Apr. 1, 1952 - Mar. 31, 1953 (The Zirconium-Oxygen System); COO-181, Mar. 31, 1953, 51 pp.

Iodide zirconium was combined with calculated amounts of $ZrO_2$ or master alloys and arc-melted. Annealing treatments were carried out at 22 temperature levels. Metallographic examination of the heat-treated specimens permitted construction of the binary phase diagram from zirconium to $ZrO_2$. Features of the diagram include the peritectic formation of beta solid solution at 1,940° C. by the reaction of L + alpha → beta. The weight-percent compositions of the reacting phases are L, 1.25 percent 0; alpha, 3.75 percent 0; and beta, 2.0 percent 0. Alpha solid solution forms directly from the melt and has a maximum melting point at 5.5 percent 0 and 1,975° C. The maximum solubility of oxygen in alpha zirconium is 6.75 percent and is apparently independent of temperature. A eutectic occurs at 11 percent 0 and 1,900° C., whereby L → alpha + $ZrO_2$. The intermediate phase $ZrO_2$, which melts at 2,700° C. has a homogeneity range extending from 23 percent 0 at 1,900° C. down to about 25 percent 0 at 700° C. No other singular phase was found between zirconium and $ZrO_2$. The variation in lattice parameters of the alpha solid solution with oxygen content was determined.

32. ARMOUR RESEARCH FUNDATION. Phase Diagrams of Zirconium-Base Alloys. Rept. 11, Apr. 1, 1953 - June 30, 1953 (The Zirconium-Nitrogen System); COO-187, June 30, 1953, 5 pp.

This report is concerned with a literature survey and alloy preparation of the zirconium-nitrogen binary system up to 50 atomic percent nitrogen.

33. ___. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 12, July 1, 1953 - Sept. 30, 1953 (The Zirconium-Nitrogen System); COO-188, Sept. 30, 1953, 9 pp.

Progress report on experimentation to determine the phase relationships in the zirconium-nitrogen binary system up to 50 atomic percent nitrogen. Preparation of materials and alloys is discussed. Analytical data on the first group of alloys are presented, and an as-cast survey of these alloys is discussed.

34. ___. Phase Diagrams of Zirconium-Base Binary Alloys. Rept. 13, Oct. 1, 1953 - Dec. 31, 1953 (The Zirconium-Nitrogen System); COO-189, Dec. 31, 1953, 9 pp.

Progress report on the experimentation to determine the phase relationships in the zirconium-nitrogen master alloys. Preparation of zirconium-nitrogen master alloys is discussed. Analytical data on the second group of alloys are presented. Metallographic examination of annealed samples has begun and is discussed.

35. ___. Phase Diagrams of Zirconium-Base Binary Alloys, Rept. No. 14, Apr. 1, 1953 - Mar. 31, 1954 (The Zirconium-Nitrogen System); COO-190, Mar. 31, 1954, 36 pp.

Phase relationships in the zirconium-nitrogen system have been determined. Due to the inability to retain nitrogen in nitrogen-rich alloys subjected to arc melting, definitive work was possible only in the range 0-30 atomic percent nitrogen. Enough complementary X-ray work was done to permit construction of the binary phase diagram up to 50 atomic percent nitrogen (ZrN). Small ingots were prepared by arc-melting master alloys with enough zirconium to produce an alloy of the desired composition. Following proper pretreatment, alloys were annealed at temperatures between 600° and 2,020° C. The phase boundaries were then determined by metallographic evaluation of specimens quenched from the various temperatures. Incipient melting techniques were used to corroborate solidus curves, and X-ray diffraction was employed to study the nitrogen-rich region of the alpha + ZRN phase field.

36. ARROE, O. H., AND MACK, J. E. Nuclear Spin 5/2 for $_{40}Zr^{91}$. Phys. Rev., vol. 76, 1949, pp. 873-874.

In interference spectrograms of a $Zr^{91}$-enriched sample of zirconium in a hollow cathode source, the $4d^25s^2\ {}^3P_0$-$4d^25s({}^2P)5p\ {}^3S_1$ line at $\nu17777$ presents the following structure, showing that the spin, I, of the interesting nucleus $_{40}Zr^{91}$ is undoubtedly 5/2 units:

| | | |
|---|---|---|
| (I + 1) | $-0.0701 \pm 0.0010$ | $cm^{-1}$,[4] |
| even isotopes | | |
| (arbitrary) | $.0000 \pm .0012$ | $cm^{-1}$, |
| (I) | $+ .0273 \pm .0010$ | $cm^{-1}$, |
| (I - 1) | $\pm .0983 \pm .0010$ | $cm^{-1}$, |
| I, from the Landé | + .58 | |
| Interval rule | 2.69 - .41 | |

37. **ARTHUR, J. S.** Specific Heats of $MgO_2$, $TiO_2$, and $ZrO_2$ at High Temperatures. Jour. Appl. Phys., vol. 21, August 1950, pp. 732-733.

Mean specific heats were determined from 20° to 800° C. for MgO, $TiO_2$, and $ZrO_2$. True specific heats were then calculated, assuming that $C_T = A + BT + CT^2$. At 350° C., the true specific heats were calculated to be MgO, 0.276; $TiO_2$, 0.210; $ZrO_2$, 0.140.

ATKINS, D. F. See abs. 670.

38. **ATO, S.** Separation and Determination of Gallium. V. Separation of Gallium From Beryllium, Titanium, Zirconium, and Thorium and the Determination of Gallium Thus Separated. Sci. Papers Inst. Phys. Chem. Res. (Tokyo), vol. 29, 1936, pp. 71-77.

A method of separating gallium was examined by extracting it completely from a solution of its chloride in hydrochloric acid by means of ether, by precipitating off the minute quantities of other elements present with it by means of ammonium hydroxide and acetate, by precipitating gallium with sodium camphorate, by igniting the precipitate, and by weighing the residue. The results are discussed.

39. **AVGUSTINIK, A. N., AND ANTSELEVICH, N. S.** (Electrical Properties of Solid Solutions in the $ZrO_2$-MgO and $ZrO_2$-CaO Systems). Zhur. Fiz. Khimii, vol. 27, No. 7, 1953, pp. 973-982.

X-ray investigation was made of composition ranges in which solid solutions and compounds are formed in the $ZrO_2$-MgO and $ZrO_2$-CaO systems. Nature of solid solution structures was also investigated. Measurements were made of permittivity (dielectric constant), dielectric loss, and electrical conductivity. The electrical properties of $CaZrO_3$ were investigated. Relaxation of weakly bound ions in vacancies-rich crystal lattices of solid solutions and effect on the electrical properties were determined.

40. **AUDLEY, J. A.** Use of Zirconia as a Refractory Material. Ceram. Soc. (England), vol. 16, 1917, pp. 121-133.

This report discusses the properties and uses of zircon.

AUSTIN, C. R. See abs. 503, 504, 505, 506, 745, 746.

AUSTIN, D. T. See abs. 135.

41. **AUSTIN, J. B.** Precocious Metals. Min. and Contract. Rev., vol. 55, No. 5, May 1953, pp. 6-11.

This report discusses titanium and zirconium, including properties, uses, potential consumption, and the basic technological problems involved in production.

42. **AXEL, P., AND FOX, J. D.** Implications of Photonuclear Effect in $Zirconium^{90}$. Am. Phys. Soc. Bull., vol. 29, No. 4, Apr. 29, 1954, p. 25.

The yields of 4.4 minute $Zr^{89m}$ and 78 hour $Zr^{89}$, both formed from $Zr^{90}$ during betatron irradiation of natural zirconium, have been studied as a function of energy. Results are given, with a brief discussion.

## B

43. **BAENZIGER, N. C., AND RUNDLE, R. E.** $MBe_{13}$ Compounds. Ames Lab., Iowa State Coll., AECD-2506, ISC-30, undated, decl. Mar. 2, 1949, 4 pp.; Acta Cryst., vol. 2, 1949, p. 258.

The compound $ZrBe_{13}$ is discussed. A lattice constant of $10.047 \pm 0.001$ A, a structure group of $O_h^6 - Fm3_c$, and face-centered positions of the zirconium and beryllium atoms are given, with the reflections that were found.

44. BAGSHAWE, B. Modern Methods of Alloy-Steel Analysis. Proc. Staffordshire Iron and Steel Inst., vol. 52, 1936, pp. 116-142.

A method is given for separating small amounts of zirconium from relatively large amounts of iron.

45. BAHL, R. K., SINGH, S., AND BALI, N. K. Study of the Periodates of Zirconium. Jour. Indian Chem. Soc., vol. 20, 1943, pp. 141-142.

$3ZrO_2.I_2O_7.14H_2O$ and $4ZrO_2.I_2O_7.18H_2O$ were formed by the action of disodium paraperiodate and potassium metaperiodate on zirconium nitrate, respectively. $6ZrO_2.I_2O_7.20H_2O$ was formed by the action of paraperiodic acid on freshly prepared zirconium hydroxide. On dehydrating this salt, lower hydrates were formed whose presence was confirmed by a study of their vapor pressures.

46. BAILEY, T. R., MUDD, J. F., AND MILWEE, J. B. Study of Selected Metallic Borides, Nitrides, and Phosphides. Univ. Louisville Inst. Ind. Res., Bimonthly Rept., July - August 1950, ATI-208121, 8 pp.

Summarizes an investigation of the literature concerning the preparation and properties of zirconium nitride. Three methods for preparing zirconium nitride were investigated: Reaction of metallic zirconium with nitrogen and with ammonia and reaction of zirconium tetrachloride with ammonia. The results obtained in these reactions are given.

47. ___. Study of Selected Metallic Borides, Nitrides, and Phosphides. Univ. Louisville Inst. Ind. Res., Bimonthly Rept., November-December 1950, ATI-208125, 9 pp.

Preparation of zirconium nitride by reacting metallic zirconium with ammonia is summarized. Employing this method, a sample of zirconium nitride was prepared. This completes investigation of the preparation of zirconium nitrides.

48. MOREL, R. W. F., WILLIAMS, G. C., AND RYERSON, F. E. Study of Selected Metallic Borides, Nitrides and Phosphides. Univ. Louisville Inst. Ind. Res., Final Report, undated, PB-112734, 52 pp.

The original project plans were to prepare the borides, nitrides, and phosphides of columbium, hafnium, indium, molybdenum, palladium, rhenium, rhodium, scandium, tantalum, thorium, vanadium, yttrium, and zirconium. A procedure was proposed for preparing these compounds. The compounds for which preparation was actually attempted were the nitrides of molybdenum, vanadium, zirconium, tantalum, and palladium; and the borides of molybdenum, tantalum boride, thorium, vanadium, and zirconium. The reactions that were investigated in preparing each compound are described. In each instance only those reactions were tried for which there was a good probability of success on the basis of theoretical considerations. The conditions under which the reactions were investigated were the optimum conditions possible with the equipment available.

49. BAIN, J. W., AND GOLLOP, G. E. Attempt to Cheapen the Production of Zirconium Dioxide. Canadian Chem. and Met., vol. 7, February 1923, pp. 35-38.

Processes of purification are investigated with the ultimate aim of producing a manufacturing method low enough in cost to permit wider application of zirconium dioxide.

BAKER, R. G. See abs. 413.

50. BALACHANDRA, J. Amalgam Metallurgy: Present Trends and Future Possibilities. Trans. Indian Inst. Metals, vol. 6, 1952, pp. 320-326.

Metal amalgams find application in the production of metals (zirconium and titanium) from their salts by reduction.

This report discusses this phase of amalgam metallurgy and its future possibilities.

51. BALDWIN, W. J. Zircon and Zirconia Refractories. Chem. Eng. Prog., vol. 44, No. 11, November 1948, pp. 875-878.

This paper covers the properties of zircon and zirconia for application as refractories and cites those special refractory fields where these material have proved advantageous.

See also abs. 390.

BALDWIN, W. M., JR. See abs. 618.

BALI, N. K. See abs. 45.

52. BALL, C. J. P. Magnesium-Zirconium Alloys. Metal Ind., vol. 75, Aug. 19, 1949, pp. 152-153.

The alloying of magnesium with zirconium has resulted in development of easily worked alloys immune to stress corrosion. This paper gives details of the composition, physical properties, and methods of working magnesium-zirconium alloys.

53. ___. Manufacture and Use of Magnesium and Its Alloys. Chem. and Ind., Aug. 21, 1948, pp. 531-536.

A brief survey of the progress of magnesium and its alloys.

54. BALLOU, N. E. Alpha-Radioactivity in Elements Lighter Than Bismuth. Phys. Rev., vol. 75, 1949, p. 1105.

Possibility of the existence of alpha-emitting nuclides of elements below bismuth in atomic number has been investigated. The liquid-drop model of the nucleus and the effects of closed shells in nuclei are utilized in arriving at conclusions. Some experimental work has been done to test conclusions, and the results obtained to date are summarized.

55. ___. Preparation of Carrier-Free Zirconium Tracer. (Ch. in Radiochem, Studies.) The Fission Products. Nat. Nuclear Energy Series, book 3, vol. 9, No. 6, (McGraw-Hill Book Co., Inc., New York, N. Y.; ed. by C. D. Coryell and N. Sugarman) 1951, pp. 1512-1513.

Presents procedure for preparing carrier-free zirconium tracer. The procedure utilizes the coseparation of zirconium activity from fission material on thorium iodate. The method is rapid, and the radiochemical yield about 80 percent. The purity of the final product is satisfactory.

See also abs. 519, 691.

BAND, W. See abs. 595.

BANERJEE, G. See abs. 178.

56. BANERJEE, S., SUNDARAM, A. K., AND SHARMA, H. D. Extraction of Cations as Salts of Fatty Acids. II. Analytical and Chromatographic Separation of Beryllium from Iron and Aluminum. Anal. Chim. Acta, vol. 10, March 1954, pp. 256-259.

Quantitative extractions of aluminum and ferric ions are carried out in the presence of butyric acid. A method has been given for quantitative extraction of beryllium from aluminum and ferric ion in presence of ethylenediaminetetraacetic acid. Interference has been studied and that due to phosphate has been avoided by adding zirconium salt. The method has been applied to the analysis of beryl.

57. BANERJI, S. N. Studies in Surface-Tension Measurements of Some Colloidal Solutions. Part III. Tannic Acid, Vanadium, Pentoxide, Zirconium Hydroxide and Ferric Hydroxide Sols. Jour. Indian Chem. Soc., vol. 30, 1953, pp. 135-138.

The surface tensions of tannic acid and of such hydrated and viscous sols as those of vanadium pentoxide, zirconium hydroxide, and ferric hydroxide have been investigated at different concentrations and temperatures, both in the presence and absence of electrolytes. The experimental results indicate that the lowering of surface tension of water in the presence of a colloidal substance originates from the presence of sufficient number of dissolved polar and aggregated molecules.

58. **BARLETT, H. B.** Note on Preliminary Work on the Preparation of Small, Dense Crucibles of Thoria-Zirconia. Massachusetts Inst. Technol., August 1945, AECD-2171, 2 pp.

Gives procedure for preparing small crucibles.

59. **BARNARD, R. L., AND TELFORD, R. E.** Titanium, Zirconium, and Hafnium. Anal. Chem., Manhattan Project, vol. 1, No. 1, 1950, pp. 469-482.

Describes procedures for micro and macro analyses of zirconium. For macro analyses, gravimetric methods were used. Cupferron and phenylarsonic acid were used as precipitants. Micro determinations were performed spectrophotometrically by using either alizarin or p-dimethylaminoazophenylarsonic acid as color reagents. Spectrographic methods were also developed.

60. **BARRETT, R. J., JR.** Zirconium and Pyribenzamine in Treatment of Ivy Poisoning. Jour. Maine Med. Assoc., vol. 43, No. 12, December 1952, pp. 376-377.

Pyribenzamine cream (2 percent) with zirconium hydrous oxide (4 percent) has a clinical use in the prophylaxis and treatment of poison-ivy dermatitis. Zirconium hydrous oxide (4 percent) in pyribenzamine cream apparently inactivates the active principle of rhus oleoresin on the skin in some chemical or physical manner, whether combined or uncombined with tissue proteins. Zirconium hydrous oxide (4 percent) apparently is not toxic in the strength used nor is it absorbed systemically by inunction in sufficient strength to influence active rhus lesions elsewhere on the body. Pyribenzamine cream with zirconium is effective in relieving the pruritis of rhus dermatitis in 24 hours and is also effective on lesions existing from a few hours to several days.

**BARSCHALL, H. H.** See abs. 88.

61. **BASKERVILLE, C.** Rare Metals X - Zirconium. Eng. Min. Jour., vol. 87, Mar. 13, 1909, p. 548.

Brief discussion of zirconium minerals and compounds and zircon.

**BASOLO, F.** See abs. 137, 138.

62. **BATES, J. I., LEWEY, F. H., AND REINERS, C. R.** Reaction of Cerebral Tissue to Silver, Tantalum and Zirconium. Jour. Neurosurgery, vol. 5, July 1948, pp. 349-353.

The reactions provoked by silver, tantalum, and zirconium ribbon when implanted in the brains and meninges of dogs for periods of time varying from 8 to 97 days are reported. The silver ribbon caused an intense inflammatory reaction in both the meninges and the nervous tissue. The tantalum ribbon caused only a minimal reaction. The zirconium ribbon provoked slightly more inflammatory reaction than tantalum, but both were benign compared with the silver. The conclusion drawn from this evidence is that tantalum and zirconium are the metals of choice for use as hemostatic clips. Silver clips should not be used.

63. **BATES, J. I., AND REINERS, C. R.** Repair of Cranial Defects With Zirconium; an Experimental Study. Jour. Neurosurgery, vol. 5, July 1948, pp. 340-348.

The criteria for choosing suitable material for repairing cranial defects have been enumerated. Inertness in tissues and adaptability to defects are the most important factors. Zirconium is an element with physical properties similar to tantalum, but it is 2-1/2 times lighter than tantalum. Zirconium has been used to repair the cranial defects of 10 dogs and to cover dural defects in 2 dogs. The longest period was 171 days. The zirconium plates retained their original luster and demonstrated the property common to all alloplastic grafts of fibrous connective-tissue capsule formation. The gross and microscopic results confirmed the relative inertness of zirconium that had been found in previous experimental work. Four zirconium plates were heated after being molded to the defect and in this manner were appreciably hardened. No increased reaction was noted after this procedure. If further experimental and clinical investigations confirm the relative inertness of zirconium in tissues, then zirconium, being lighter, more malleable, and cheaper than tantalum, will be a more satisfactory metal for repairing cranial defects.

64. **BATES, J. I., REINERS, C. R., AND HORN, R. C.** Discussion of the Uses of Metals in Surgery and an Experimental Study of the Use of Zirconium. Surg. Gynecol. Obstet., vol. 87, 1948, pp. 213-220.

The use of metals in surgery and the principles of the reaction of tissues to metal have been discussed. Four metals, Vitallium, Ticonium, "18-8-SMO" stainless steel, and tantalum have proved to be passive enough for use in the human body. A new metal, zirconium, has been studied experimentally. Zirconium is an element that has physical properties similar to tantalum, but it is 2-1/2 times lighter. Both are electrolytically inert. The tissue reaction caused by zirconium sutures, placed in the rectus fascia of dogs, was minimal. Intramedullary zirconium pins and bone screws provoked only very slight reaction at 12 weeks. Zirconium, which has proved to be a lighter, more malleable, and cheaper metal than tantalum, warrants further study regarding its use in surgery.

65. **BATTELLE MEMORIAL INSTITUTE.** Development of Titanium-Base Alloys; Summary Report Covering the Period July 1, 1950 to May 18, 1951. AF-TR-6623, June 18, 1951, 166 pp.

Data on the mechanical properties of titanium-zirconium, iron-molybdenum-titanium-zirconium, and chromium-iron-titanium-zirconium alloys are given (TID-3010-1).

66. ___. Research and Development on Titanium Alloys; Part 2, May 18, 1949 to June 30, 1950. AF-TR-6218 (Part 2), June 30, 1950, 178 pp.

Alloys containing 1 to 10 percent zirconium were investigated. A zirconium content of 10 percent increased the strength of Process A titanium metal to - 37,000 p.s.i. On aging for 4 hours at 750° F., these alloys showed a small but definite increase in strength and hardness. Zirconium limited the alpha-phase field and lowered the beta transus. It is concluded that zirconium is less effective as an alloying addition than chromium, manganese, or molybdenum but may have some advantages in complex alloys. The mechanical properties of titanium-zirconium alloys as-rolled and as-rolled and aged are listed in tabular form. Zirconium additions to titanium appear to have strengthening effects. The phase present in titanium-zirconium alloys, as quenched from temperatures of 1,450° to 1,750° F., are shown graphically. Hardness and minimum bend radii for the titanium-zirconium alloys following different solution heat-treatments are tabulated (TID-3010).

**BEALL, R. A.** See abs. 831.

67. **BEAUDET, E. C.** Allegheny Ludlum Hot-Extrudes Stainless, High-Alloy Steels. Iron Age, vol. 173, No. 12, Mar. 25, 1954, pp. 137-140.

Stainless and high-alloy seamless tubing and shapes are now being hot-extruded on a commercial basis at Allegheny Ludlum's integrated extrusion plant at Watervliet, N. Y. All standard

300 and 400 series grades are used. Seamless tubing, 1-5/8 to 4 inches in diameter and 12 to 45 feet in length, can be produced at a rate of 25 to 30 pushes per hour. When not running on tubing, press capacity is filled in with production of shapes 0.5 to 3.0 square inches in cross-sectional area and 12 to 60 feet in length. Titanium, zirconium, tool steels, and high-temperature alloys are being extruded experimentally, with good results. The integrated plant has facilities for handling production from billet to finished product.

68. BECK, P. A. Notes on Work Hardening and Recovery. Acta Met., vol. 1, No. 4, July 1953, pp. 422-425.

Although the available data are not conclusive, the annealing processes in cold-worked metals may be subdivided into at least three distinct stages, which occur successively with increasing annealing time or temperature (apart from overlapping) in the following order: (1) Recovery (without interface migration), (2) subboundary migration (gradual subgrain growth essentially without reorientation), and (3) grain boundary migration ("recrystallization," with local reorientation, the discontinuous growth of some crystal fragments with strongly deviating orientations). It appears that most of the stored energy of cold work and a minor component of the work hardening are released in recovery, while subgrain growth is capable of releasing the remaining larger portion of work hardening, which is connected with the subboundaries. However, the third stage of annealing ("recrystallization") often sets in prematurely and then it takes over from subgrain growth the function of relieving a large fraction of the work hardening.

BECKER, R. A. See abs. 732.

69. BECKET, F. M. Some Effects of Zirconium in Steel. Iron Age, vol. 111, 1923, pp. 1321-1323.

This paper covers some specific effects of zirconium as determined in the course of an investigation that has involved 350 experimental heats of steel.

BECKETT, C. W. See abs. 740, 741.

BEINLICH, A. W., JR. See abs. 625.

70. BELCHER, R., AND GOULDEN, R. Analysis for Industry. Ind. Chem., vol. 26, December 1950, pp. 522-524.

New reagents, sodium flavianate, mandelic acids, and halogen-substituted mandelic acids are discussed in connection with their use in separating and precipitating zirconium.

71. BELCHER, R., SYKES, A., AND TATLOW, J. C. Mandelic Acid and Halogen-Substituted Mandelic Acids as Reagents for the Determination of Zirconium. Anal. Chim. Acta, vol. 10, No. 1, 1954, pp. 34-47.

o-, m- and p-fluoro- and -trifluoromethylmandelic acids have been prepared and their value as precipitants for zirconium assessed. Although the p-derivatives are satisfactory, there are no obvious advantages in their use. Direct weighings of zirconium mandelate and p-bromomandelate, about which there have been conflicting reports in the literature, have been investigated also. p-bromomandelic acid has been employed successfully for determining amounts of zirconium oxide between 3 and 50 mg. per 100 ml., but ignition of the precipitate to zirconium oxide is necessary. Of the acids examined, mandelic itself gives the only precipitate that is almost constant and stoichiometric in composition. The composition of this compound, however, varies slightly with the amount of zirconium present in the solution under test, and though an overall empirical factor an be applied its use is recommended only if a high order of accuracy is not required. If a series of determinations in a narrow range is to be carried out by direct weighing of zirconium mandelate, more accurate results might be obtained by determining the appropriate factor for that range.

BELLE, J. See abs. 512.

72. **BELLE, J., CLELAND, B. B., AND MALLETT, M. W.** Kinetics of the Reaction of Hydrogen With Zirconium. Jour. Electrochem. Soc., vol. 101, No. 5, May 1954, pp. 211-214.

The rate of reaction of hydrogen with high-purity zirconium was determined for the temperature range of 250° to 425° C. at 1 atm. pressure. The reaction was found to follow a parabolic law and the parabolic rate constant, in $(ml./cm.^2)^2$ per second, was calculated to be $k = 2.3 \times 10^5 e^{-17,200/RT}$, where 17,200 ± 200 cal./mole is the activation energy for the reaction.

73. **BELLE, J., AND MALLETT, M. M.** Kinetics of the High-Temperature Oxidation of Zirconium. Jour. Electrochem. Soc., vol. 101, No. 7, July 1954, pp. 339-342.

The rate of oxidation of high-purity zirconium was determined for the temperature range of 575° to 950° C. at 1 atm. pressure. Data can be fitted to a cubic law and the rate constant in $(ml./cm.^2)^3/sec.$ has been calculated to be $k = 3.9 \times 10^6 e^{-47,200/RT}$, where 47,200 ± 1,000 cal./mole is the activation energy for the reaction.

74. **BELOZERSKII, N. A., AND KUCHERENKO, O. A.** (Physicochemical Properties of the Rare Metals. II. Phase Diagram of the Systems $ZrCl_4$ - NaCl and $ZrO_2$ - $CaCl_2$.) Jour. Appl. Chem. (U. S. S. R.), vol. 13, No. 11, 1940, pp. 1552-1555.

The binary systems $ZrCl_4$ - NaCl and $ZrO_2$ have been investigated to determine solubilities and detect complex chemical compounds.

75. **BELYANKIN, D. S., AND LAPIN, V. V.** (Zirconium Dioxide in Mullite Refractories.) Doklady Akad. Nauk S. S. R. R., vol. 73, No. 2, 1950, pp. 367-369.

Preliminary study was made of beneficial effect of small additions of zirconium concentrate upon recrystallization and properties of fusion-made mullite. Composition (chemical and mineralogical) of mullite was used in study. Results of mineralogical examination gave particles on the various components and form and distribution of zirconium dioxide in mullite samples.

**BENDELL, W. L.** See abs. 732.

76. **BENDER, H.** High-Temperature Metal Ceramic Seals. Ceram. Age, vol. 63, No. 4, April 1954, pp. 15-17, 20, 21, 46-50.

Two processes are described in detail for bonding ceramics to metals or to other ceramics. The first of these, the Telefunken process, consists essentially of bonding molybdenum powder to a ceramic and then brazing to this metallized ceramic with silver. It has been utilized for bonding molybdenum to zircon. The second process, the hydride method, utilizes $TiH_2$ or $ZrH_2$ layers on the ceramic. Silver, copper, and lead, or their alloys may be used as the braze, and a bond is formed when the hydride is decomposed thermally. This occurs in practice in the range 600° to 700° C. above the melting point of lead and generally below the melting point of silver and copper alloys.

77. **BENEDICT, J. T., SCHUMB, W. C., AND CORYELL, C. D.** Distribution of Zirconium and Hafnium Between Cation-Exchange Resin and Acid Solutions. The Column Separation With Nitric Acid-Citric Acid Mixtures. Jour. Am. Chem. Soc., vol. 76, No. 8, Apr. 20, 1954, pp. 2036-2040.

A survey has been made, using radioactive tracers, of the distribution of zirconium and hafnium between solutions containing varying concentrations of sulfuric, hydrochloric, or nitric acids and the cation-exchange resin Dowex-50. Since the differences in behavior of the two elements were not great, attention was also given to the effects of varying concentrations of oxalic, tartaric,and citric acids in nitric acid. These data cast light on the chemical behavior of the elements in acid solution. A gross difference in the distribution coefficient in a solution of 0.45 M in nitric acid and 0.09 M in citric acid was exploited by using this solution as eluent for the elements from an ion-exchange column; the column separation was very effective in removing the zirconium from the more slowly eluted hafnium.

BENNETT, D. G. *See* abs. 843.

BENSON, N. D. *See* abs. 193.

BERG, M. *See* abs. 443.

BERGER, M. J. *See* abs. 290.

BERMAN, J. *See* abs. 475.

BERRY, B. E. *See* abs. 738.

78. BEVINGTON, C. F. P., MARTIN, S. L., AND MATHEWS, D. H. Absorption of Gases by Titanium and Zirconium. Proc. Internat. Cong. Pure and Appl. Chem. (London), vol. 3, 1947, pp. 3-16.

Isotherms and isobars are given. H-metal systems exhibit 2-phase isotherms in some pressure and temperature ranges. The solubility in zirconium is 5 atomic percent for hydrogen, 30 percent for oxygen, and smaller for nitrogen. Solubility of carbon in zirconium is indicated. In titanium the absorption is 30 atomic percent for hydrogen, 30 percent for oxygen. The data for hydrogen in titanium appear questionable. In general, it appears that the nonmetal atoms can take up positions in the octahedral holes of the metal lattice, where they assume a slightly negative charge, becoming strongly bound but mobile; as a result they expand the metal lattice, increase the density, and decrease the electrical conductivity. Mechanical properties of the metals are also strongly affected. The presence in the metal lattice of other atoms considerably lowers the H-sorbing capacity. The oxygen, nitrogen, and carbon atoms cause a shift in discontinuous regions of the isotherms toward higher temperatures and pressures. The effect on the lattice expansion and hydrogen sorption appears to increase in the order oxygen, nitrogen, carbon, which is the order of increase for the atomic radii. (Chem. Abs.)

79. BEYER, G. H., SPINK, D. R., WEST, J. B., AND WILHELM, H. A. Caustic Treatment of Zircon Sand. Ames Lab., Iowa State Coll., ISC-437 (Rev.), Aug. 17, 1954, 14 pp.

The most abundant domestic zirconium ore is zircon (zirconium silicate). Caustic soda was found to be effective in decomposing this ore. Using a caustic: zircon weight ratio of 1.1:1 and a furnace temperature of 1,050° F. it was found that 80-90 percent of the zircon reacted to form water-soluble sodium silicates and water-insoluble sodium zirconates. The zirconates were readily converted, after leaching with water, to high-purity zirconium compounds, such as the oxychloride, fluoride, sulfate, hydroxide, oxide, and nitrate. The low caustic:zircon ratio and the simple equipment for decomposing the sand without previous grinding make this process convenient and economically attractive.

80. BINKS, W. Crystalline Structure of Zircon. Mineral. Mag. and Jour., Mineral. Soc., vol. 21, 1926, pp. 176-187.

Zircon, $ZrSiO_4$, has been examined by the ionization spectrometer and by a Debye-Scherrer powder photograph. The lattice upon which the structure is based corresponds to the space-group $D^{19}_{4n}$, possessing the symmetry of the ditetragonal-bipyramidal class. The unit cell, containing 8 molecules of $ZrSiO_4$, has the dimensions $\alpha = 9.30$, c = 5.93 Å. The silicon and zirconium atoms form two interpenetrating face-centered lattices. Eight diagonal axes pass vertically through each unti cell, and on each axis are situated 1 silicon and 1 zirconium, lying at a distance c./2 apart. Symmetry considerations limit the assembling of oxygen atoms to tetrahedra, each enclosing a silicon atom. All the atoms in the structure are situated on reflection planes. The structure resembles in some ways that of anhydrite, $CaSO_4$, an account of which appears in another paper. The analogous dispositions of atoms in the planes (110) in zircon and in the planes (001) in anhydrite is most interesting. The distribution of atoms about the c-axis in zircon is similar to that about the alpha axis in anhydrite.

81. BIRKS, L. S., AND BROOKS, E. J. Quantitative Analysis of Hafnium-Zirconium and Tantalum-Columbium Systems by X-Ray Fluorescence. Naval Research Lab., NP-1371, Dec. 16, 1949, 9 pp.

The X-ray fluorescence-analysis method was adapted to determine small amounts of hafnium in zirconium and tantalum in columbium. Curves of the relative intensity of spectral lines of tantalum and columbium or hafnium and zirconium were plotted against percentage composition by using prepared standard compositions. As an example of the accuracy attainable, a 0.5 atomic percent tantalum in columbium specimen was measured to ± 0.02 percent, or 4 percent of the amount of tantalum present, with a total counting time of about 3 to 5 minutes.

BIRMINGHAM, J. M. See abs. 825.

BLACK, D. G. See abs. 3.

82. BLOCHER, J. M. Twins in the "Wonder-Metal" Family. Battelle Tech. Rev., vol. 2, No. 9, September 1953, pp. 99-100.

A brief article on the importance, applications, and properties of zirconium and titanium.

83. BLOKHIN, M. (X-Ray-Spectroscopic Quantitative Analysis of Niobium, (Columbium) Yttrium, and Strontium in Zirconium Minerals.) Tech. Phys. U. S. S. R., vol. 5, 1938, pp. 147-152.

The study was carried out by comparison on the spectrograph by the Cauchois method, taking into account the various factors that might affect the results. Comparison of the results with those obtained by chemical analysis shows good agreement.

BLUMENTHAL, H. See abs. 599.

84. BLUMENTHAL, W. B. Some Properties of Zirconium Compounds Significant to the Cosmetic Technologist. Jour. Soc. Chem., vol. 4, No. 2, August 1953, pp. 69-75.

A survey of zirconium compounds that have properties of value for cosmetic and pharmaceutical applications with no toxic or other physiologically undesirable effects. Applications specifically indicated are as antipruritics and body deodorants.

85. ___. Toward a System of Zirconium Chemistry. Ind. Eng. Chem., vol. 46, No. 3, March 1954, pp. 528-539.

This paper gives the fundamental properties of zirconium that are widely manifested in its compounds; it is shown that the composition of zirconium compounds and much of their chemical behavior follow simply from the operation of principles derived from these fundamental properties. General patterns of reactions are stated in mathematical terms, and graphic formulas showing general and specific reactions are given.

86. ___. Zirconium Chemicals. Part I. Their Application to Textiles. Part II. Their Use in Water Repellent Treatment of Textiles. Part III. Hygienic Aspects of Treating Textiles With Zirconium Chemicals. Rayon and Synthetic Textiles, vol. 31, No. 12, December 1950, pp. 81-83; vol. 32, No. 1, January 1951, pp. 85, 86, 88; vol. 32, No. 4, April 1951, pp. 79, 80, 82.

This is a series of three articles on the application of zirconium chemicals to the improvement of certain qualities of textiles. Part 1 describes the theory and practice of current applications, gives data on the extent of their use, and outlines the possibilities for broader exploitation of zirconium treatments. Part 2 gives the technology of water-repellance with zirconium compounds. Part 3 treats the hygienic aspects of zirconium chemicals.

87. BLUMENTHAL, W. B. Zirconium Widens Its Industrial Orbit. Chem. Ind., vol. 65, 1949, pp. 728-730.

History, production, and uses are covered in this report.

88. BOCKELMAN, C. K., PETERSON, R. E., ADAIR, R. K., AND BARCHALL, H. H. Total Cross-Section Measurements for Fast Neutrons. Univ. of Wisconsin, AECU-288, 1949, 10 pp.

The total cross sections of zirconium, silver, indium, antimony, iodine, tantalum, and lead have been measured as a function of neutron energy in the energy range from 20 to 1,600 kev. A spread in energy of 30 kev. was used up to 200 kev., and a spread of 70 kev. above this energy. Indications of structure were found in zirconium and lead. The results are compared with the predictions of the statistical theory.

BOEHM, F. See abs. 521.

89. BOGAN, L. C. Review of the Effects of Titanium and Zirconium in Steel. Australasian Eng., vol. 45, July 7, 1953, pp. 51-55.

This report stresses that the practical functions of titanium and zirconium in steel manufacturing and applications are associated with the strong chemical affinities these elements have for oxygen, nitrogen, carbon, and sulfur. Thus, two board divisions arise within the commercial uses of titanium and zirconium in steel manufacture. The first of these is concerned with deoxidation and scavening generally, while the second relates to their true alloying properties. The alloying functions of these elements are dominated by their strong carbide-forming habits, and virtually all their commercial uses as alloying elements in steel are related in some degree to carbide stabilization. Neither element can be regarded as a major alloying agent in steel manufacture, and it is unlikely that this state of affairs will alter materially in the near future.

90. BOLLINGER, L. M., HARRIS, S. P., HIBDON, C. T., AND MUEHLHAUSE, C. O. Neutron Absorption and Scattering by Hafnium. Phys. Rev., vol. 92, No. 6, Dec. 15, 1953, pp. 1527-1531.

Thermal activation, thermal absorption, resonance scattering, resonance transmission, and multiplicity of captured gamma rays have been measured for the stable isotopes of hafnium. Isotopic assignments of the various resonance levels are presented that are consistent with all the data observed. Where possible, the level spacing is estimated.

91. BOONSTRA, J. P. (Modification of Sanchis' Method for the Determination of Fluoride in Drinking Water.) Rec. trav. chim., vol. 70, 1951, pp. 325-330.

By an alteration of the zirconium: alizarin ratio in the reagent the sensitivity of Sanchis' method is so increased that the latter becomes suitable for a determination with the aid of a photoelectric colorimeter.

BORG, J. O. See abs. 831.

BOULGER, F. W. See abs. 739

92. BOWEN, I. S., AND MILLIKAN, R. A. Stripped Yttrium ($Y_{III}$) and Zirconium ($Zr_{IV}$). Phys. Rev., vol. 28, November 1926, pp. 923-926.

Using aluminum electrodes, first with yttrium oxalate and borax fused into their cores and second with zirconium hydroxide replacing the yttrium oxalate, the hot spark spectra of $Y_{III}$ and $Zr_{IV}$ have been identified and the series relationships and term values analyzed. The results are tabulated. In these stripped atoms the normal position of the electron is in a 4d orbit rather than in a 5s.

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**BOYER, M. H.** See abs. 775.

**BRADLEY, D. C.** See abs. 805.

93. **BRADLEY, D. C., HALIM, F. M. A., MEHROTRA, R. C., AND WARDLAW, W.** Reactions of Acetyl Chloride With Zirconium Alkoxides. Jour. Chem. Soc., December 1952, pp. 4609-4612.

Reactions of primary, secondary, and tertiary alkoxides of zirconium with acetyl chloride have been investigated and the following new compounds prepared: $ZrCl_4$, $Pr^nOAc$; $ZrCl_4$, 2 $Pr^iOAc$; $ZrCl_2(OPr^i)_2$, $Pr^iOH$; $ZrCl(OPr^i)_3$,$Pr^iOH$; and $ZrCl(OPr^i)_3$. No hydrogen chloride was evolved in reactions involving $Zr(OPr^i)_4$. $Pr^iOH$, and acetyle chloride, even in the presence of excess of isopropyl alcohol; and $ZrCl_3(OP^i)$, $2Pr^iOH$ was obtained by treating $Zr(OPr^i)_4$,$Pr^iOH$ with hydrogen chloride. Radical-interchange reactions involving chloride alkoxides of zirconium are demonstrated and mechanisms of radical interchange between chlorides and alkoxides of silicon, titanium, and zirconium are discussed.

94. **BRADLEY, D. C., HALIM, F. M. A., AND WARDLAW, W.** Chloride Ethoxides of Zirconium. Jour. Chem. Soc., pt. 4, 1950, pp. 3450-3454.

Reaction of $ZrCl_4$ with ethanol yielded the compounds $ZrCl_3(OEt)$, EtOH(I), and $ZrCl_2(OEt)_2$(II). Thus the order of reactivity with ethanol is $SiCl_4 > TiCl_4 > ZrCl_4 > ThCl_4$. By reactions involving (I), (II), or $Zr(OEt)_4$ with acetyl chloride the following new compounds of zirconium have been prepared: $ZrCl_4$, $CH_3.CO_2ET$; $ZrCl_3(OEt)$, $CH_3.CO_2Et$; $ZrCl_2(OEt)_2$, EtOH; $ZrCl_2(OEt)_2$, $Ch_3.CO_2Et$; and $ZrCl(OEt)_3$. The stability of the compounds formed by the coordination of a molecule of ethyl alcohol or ethyl acetate with $ZrCl_3(OEt)$, $ZrCl_2(OEt)_2$, or $ZrCl(OEt)_3$ decreased as chlorine was replaced by ethoxide.

95. **BRADLEY, D. C., MEHROTRA, R. C., AND WARDLAW, W.** Hafnium Alkoxides. Jour. Chem. Soc. (London), May 1953, pp. 1634-1636.

The alkoxides of hafnium, $Hf(OR)_4$, where R = Me, Et, $Pr^i$, $Bu^t$, and tertiary-amyl, have been prepared, their boiling points are lower than those of the corresponding zirconium compounds. Hafnium tertiary-amyloxide has a slightly higher latent heat and entropy of vaporization and a greater molecular volume than the zirconium analogue. The relative volatilities of zirconium and hafnium alkoxides are discussed.

96. ____. Structural Chemistry of the Alkoxides. Part I. Amyloxides of Silicon, Titanium, and Zirconium. Jour. Chem. Soc., June 1952, pp. 2027-2032.

The isomeric amyloxides $M(OC_5H_{11})_4$ of titanium and zirconium have been prepared by alcoholysis. Boiling points (under reduced pressure) and molecular weights of these compounds and of n-amyl and neopentyl orthosilicates have been measured. The influence of branching of the amyl group on the physical properties of these compounds is discussed.

97. ____. Structural Chemistry of the Alkoxides. Part III. Secondary Alkoxides of Silicon, Titanium, and Zirconium. Jour. Chem. Soc., December 1952, pp. 5020-5023.

The secondary alkoxides, $M(O.CHR_2)_4$, where R = Me, Et, $Pr^n$, $Pr^i$, or $Bu^n$, and $M(O.CHMeR)_4$, where R = Et, $Pr^n$, $Pr^i$, $Bu^n$, $Bu^t$, or n-hexyl, and M = titanium or zirconium, have been prepared, and also isopropyl and sec.-amyl orthosilicates. Boiling points and, in some instances, vapor pressures and molecular weights have been measured. The results support the theory that steric effects are most important in determining the physical properties of the alkoxides. Entropies of vaporization for $Si(OPr^i)_4$, $Si(O.CHEt_2)_4$, $Ti(OPr^i)_4$, and $Ti(O.CHEt_2)_4$ exhibit some anomalous relations that are discussed.

98. **BRADLEY, D. C., MEHROTRA, R. C., SWANWICH, J. D., AND WARDLAW, W.** Structural Chemistry of the Alkoxides. Part IV. Normal Alkoxides of Silicon, Titanium, and Zirconium. Jour. Chem. Soc., July 1953, pp. 2025-2030.

The normal alkoxides, $Ti(OC_nH_{2n+1})_4$, where n = 2, 3, 4, 5, 6, 7, and 8, and $Zr(OC_nH_{2n+})_4$, where n = 2, 3, 4, 5, 6, and 8 have been prepared and their molecular weights and boiling points measured. Molecular complexity is virtually independent of chain length, while boiling points increase linearly with molecular weight. Structures for the complex alkoxides are discussed. Vapor pressures and vapor densities were measured for zirconium tetraethoxide and tetraisopropoxide, and it is suggested that the vaporization process is $(Zr(OR)_4, n$ (liquid), $nZr(OR)_4$ (vapor), and that the energy of intermolecular attraction is about 18 kcal./mole. Entropies of vaporization for the n-alkoxides of silicon and titanium increase with chain length, and this behavior is discussed in terms of molecular "entanglement" in the liquid state.

99. BRADLEY, D. C., AND WARDLAW, W. Jour. Chem. Soc., pt. 1, 1951, pp. 280-285.

From the reaction between sodium ethoxide and zirconium tetrachloride in ethyl alcohol, a complex sodium-zirconium ethoxide has been isolated, but its composition does not accord with the formula $[(NaH\ Zr(OEt)_6]$ reported by Meerwein and Bersin. Zirconium alkoxides have been prepared by treating solutions of zirconium tetrachloride in appropriate alcohols with anhydrous ammonia. The products are impure due to hydrolysis, which becomes very marked when secondary and tertiary alcohols are used. The cause of this hydrolysis is discussed. Ester-interchange has been successfully used for preparing various types of zirconium alkoxide. Tentative views are advanced to account for the interesting variation of the volatility of zirconium alkoxides with structure of the alkyl group.

100. BRADSHAW, F. J. Optical Emissivity of Titanium and Zirconium. Proc. Phys. Soc. (London), No. 63-B, 1950, pp. 573-577.

A method of measuring the optical emissivity of titanium and zirconium, using eddy current heating is described. The specimen consisted of a cylinder of metal drilled with a small black-body hole, and its real and apparent temperatures were measured with an optical pyrometer at a mean wavelength of 0.652 $\mu$. The variation of emissivity with temperature was investigated, and the precautions taken to avoid errors are described.

101. **BRADY, E. L. Preliminary Study of the 17th $Zr^{97}$ Chain. (Ch. in Radiochemical Studies.) The Fission Products. Nat. Nuclear Energy Series, book 2, vol. 9, No. 5 (McGraw-Hill Book Co., Inc., New York, N. Y.; ed. by C. D. Coryell and N. Sugarman), 1951, pp. 703-704, MDDC-1694D.**

**The chain 17th Zr75m niobium is a prominent one in fission. Considerations of fission yield and preparation by cross bombardment show that its mass assignment is 97.**

102. **BRADY, E. L., AND ENGELKEMEIR, D. W. Phosphate Method for Determination of Zirconium and Niobium Activities in Fission. (Ch. in Radiochemical Studies.) The Fission Products. Nat. Nuclear Energy Series, book 3, vol. 9, No. 6 (McGraw-Hill Book Co., Inc., New York, N. Y.; ed. by C. D. Coryell and N. Sugarman), 1951, pp. 1491-1494, MDDC-1223.**

**Presents procedure for tandem isolation of zirconium and niobium (columbium) from fission material. The method utilizes the precipitation of zirconium and niobium in a 0.5M $H_3PO_4$ solution to separate these elements from the other fission activities. The separation of niobium and zirconium from each other is based on the formation of a soluble complex of niobium when a precipitate of $ZrO_2$ and $Nb_2O_5$ is fused with $K_2CO_3$.**

103. **BRAND, F., JACOBS, H., AND LoCASCIO, C. Experiments in the Design of Ceramic Electron Tubes.**

Original from THE OHIO STATE UNIVERSITY

Ceram. Age, vol. 63, No. 5, May 1954, pp. 18-23.

The purpose of this paper is to present a survey of the results arrived at in the course of experiments and studies involving vacuum tight ceramic-to-metal seals.

BREMER, R. F. See abs. 223.

BRENNER, A. See abs. 718.

104. BREWER, L. Thermodynamic Properties of the Oxides. Radiation Lab., Univ. of California, UCRL-104, July 1948, 46 pp.

The thermodynamic phase relations and properties of the oxides are tabulated.

BRICE, M. K. See abs. 162.

105. BRICK, R. M., LEE, H. T., GREENWALD, H., DUNKERLEY, F. J., MILLS, G. J., AND PLEDGER, F. Preparation of Single Crystals of Beryllium and Zirconium; Study of Mechanical Properties and Recrystallization and Grain Growth Characteristics of Beryllium and Zirconium. Univ. of Pennsylvania, Project Status Rept., Oct. 1, 1949, to Jan. 1, 1950; NP-1420, Jan. 1, 1950, 9 pp.

The recrystallization of zirconium has been studied. Details are given of material preparation, techniques used, and tests made. Results show that zirconium reduced 15 percent recrystallizes at 500° C., while metal reduced 20 percent recrystallizes at 450° C.

106. ___. Part I. Preparation of Single Crystals of Beryllium and Zirconium; Study of Mechanical Properties. Part II. Recrystallization and Grain Growth Characteristics of Beryllium and Zirconium. Univ. of Pennsylvania, Periodic Status Rept., Jan. 1, 1950, to Apr. 1, 1950, 9 pp.

Part I. Twenty-one melts of beryllium have been made in attempts to produce single crystals by the Bridgman method. Many variants of the one previous successful run were tried, but all attempts have been bi- or tri-crystals at best. Small single-crystal specimens are now being cut from the M. I. T. ingot; and, despite lesser perfection of the structure and greater analytical difficulties, these will be deformed in compression, varying the temperature and orientation of stressing. Part II. Recrystallization data obtained from hardness measurements and metallographic techniques are reported at 2 strain levels and at 3 temperatures for zirconium containing the second phase: (1) Agglomerated in the grain boundaries and (2) distributed as lamellas in an alpha-zirconium matrix. The percentage recrystallized in the various specimens determined by the metallographic and hardness techniques did not agree satisfactorily because of the influence of the second phase. X-ray studies are now in progress in an attempt to resolve this lack of agreement. Evaluation of energy of activation for recrystallization and a more detailed interpretation of the data are reserved for the final report. Grain-growth data obtained for 2 different initial grain sizes at 5 temperature levels were found to yield straight lines on a graph of log D versus log t plot.

107. BRICK, R. M., LEE, H. T., AND GREENWALD, H. Preparation of Single Crystals of Beryllium and Zirconium; Study of Mechanical Properties. Univ. of Pennsylvania, Periodic Status Rept., Apr. 1, 1950, to July 1, 1950; NP-3575, July 1, 1950, 3 pp.

Long-time annealing at 800° C. in vacuum has been found to eliminate the second phase from iodide zirconium sheet of 0.010 inch thickness. X-ray diffraction studies of the metal and of the deposits formed on the wall of the vacuum container have not yet provided an identification of the second phase or its major components. Grain growth in the "de-second phased" metal suggests that small single crystals may now be producible from this 0.010-inch-thick metal. (TID-3010, suppl. 1.)

108. BRICK, R. M., LEE, H. T., AND GREENWALD, H. Preparation of Single Crystals of Beryllium and Zirconium; Study of Mechanical Properties. Univ. of Pennsylvania, Quarterly Rept., Jan. 1, 1951, to Apr. 1, 1951; NP-3112, Apr. 1, 1951, 5 pp.

The effects of oxygen and nitrogen in the microstructure, hardness and lattice parameters of iodide zirconium have been determined. It is concluded that: (1) Dissolution of oxygen displaces the second phase usually observed in iodide zirconium from the surface inward; (2) nitrogen is soluble in c.p.h. or alpha zirconium to less than 0.5 atomic percent; (3) neither oxygen or nitrogen affects the lattice parameters of zirconium enough to use parameters as an analytical tool.

109. BRICK AND CLAY RECORD. Applications of Zirconium Silicates and Oxides. Vol. 104, No. 5, 1944, pp. 46, 48.

Discusses importance of zircon to the refractories industry. Topics covered in detail include properties of zircon grog bricks, grog-type zircon refractories, fine-grained zircon refractories, cast zircon refractories, zircon cements, and coatings.

110. BRIDGMAN, P. W. Compressibility and Pressure Coefficient of Resistance of Zirconium and Hafnium. Proc. Am. Acad. Arts and Sci., vol. 63, 1928, pp. 347 - 350.

Procedures are given for the measurement of compressibility and resistance under pressure of zirconium and hafnium.

111. ___. Electric Resistance to 30,000 kg./cm.$^2$ of Twenty-Nine Metals and Intermetallic Compounds. Proc. Am. Acad. Arts and Sci., vol. 79, 1951, pp. 149-179.

Pressure measurements have been worked out so that the slight deviations from linearity in the manganin gage can be determined for any particular manganin coil by reference to two pressure-fixed points. It is therefore indicated that the resistance measurements should be extended to 30,000 kg./cm.$^2$ for other metals which show a smaller effect of pressure and a closer approach to linearity. In this report, data are presented for all presently available metals which satisfy this description. The material of the measurements in many cases is the identical specimen which was formerly measured in the range to 12,000 kg./cm.$^2$; in fact, all former material has now been remeasured over the wider range, except in those instances where material purer than that formerly used is now available. Where the identical material was not used, an indication of the probable purity of the present material has been attempted by measuring the temperature coefficient of resistance at atmospheric pressure. The present measurements were made at room temperature instead of over the temperature range between 0° and 100° as formerly to 12,000°.

112. ___. Rough Compressions of 177 Substances to 40,000 kg./cm.$^2$. Proc. Am. Acad. Arts and Sci., vol. 76, 1948, pp. 71-87.

In a previous paper an apparatus has been described for rapid determination of the compression of solids at room temperature to high-pressures and the compression of 61 fairly compressible solids determined with it to 25,000 kg./cm.$^2$. The same apparatus is the subject of this report; with minor modifications, it has been carried to 40,000 kg./cm.$^2$ and the compression of 177 substances, including zirconium, determined with it. Data are presented in detail.

113. BRIGGS, S. H. C. Preparation of Some Metallic Chromates. Jour. Chem. Soc., 1929, pp. 242-245.

Describes a method for preparing zirconium chromate.

114. BRITISH INTELLIGENCE OBJECTIVES SUBCOMMITTEE. General Survey of Work

by Dr. Ryschkewitsch, Largely in Field of Ceramics. PB-97646; B. I. O. S. Misc. 107, May 14, 1946, 110 pp.

This paper is subdivided into 5 parts. Part V contains a discussion of the chemical resistance of sintered oxides, especially of crucibles for laboratory use made of $Al_2O_3$, BeO, $ZrO_2$, $ThO_2$, and spinel. The results are expressed in curves of "integral corrosion" at constant temperatures with molten $Na_2CO_3$ and NaOH. Under special conditions, the chemical resistance of BeO can be considerably improved (TID-3010).

115. **BRITTON, H. T. S.** Electrometric Studies of the Precipitation of Hydroxides. Part II. Precipitation of the Hydroxides of Zinc, Chromium, Beryllium, Aluminum, Bivalent Tin, and Zirconium by Use of the Hydrogen Electrode, and Their Alleged Amphoteric Nature. Jour. Chem. Soc., vol. 127, 1925, pp. 2120-2141.

The hydrogen-ion concentrations ruling throughout the precipitation of the hydroxides, of aluminum, beryllium, zinc, chromium, stannous tin, and zirconium have been investigated. New light has been thrown on the nature of the characteristic soluble basic salt solutions of beryllium, chromium, and zirconium. The mechanism of precipitation of stannous and zirconium hydroxides has been shown to be that of the formation and subsequent coagulation of a colloidal solution of dispersed basic chloride particles. It has been shown that, of the bases studied in this paper, aluminum hydroxide is the only one that is definitely amphoteric. No confirmation of the observations of Hildebrand on zirconium and zinc hydroxides could be obtained. The study of zirconium chloride and sulfate solutions has revealed that both are composed of highly dispersed basic particles and hydrolyzed acid. No evidence could be obtained of the existence of the "zirconyl" radical.

116. **BRITTON, H. T. S., AND GERMAN, W. L.** Physiochemical Studies of Complex Acids. Part V. Precipitation of Tungstates. Jour. Chem. Soc., 1931, pp. 709-717.

The change in the hydrogen-ion concentration of diluted aqueous solutions of $ThCl_4$, $ZrCl_4$, $BeSO_4$, $Al_2(SO_4)_3$, $K_2SO_4$, $Cr_2(SO_4)_3$, $CuSO_4$, $MgSO_4$, and $NiSO_4$ on titration with 0.045 M $Na_2WO_4$, $3Na_2$ $0.7WO_3$, and $Na_2$ $0.4WO_3$ solutions is followed with the quinhydrone and the $H_2$ (when the precipitation range is above pH 7) electrodes. In general, the pH values at which precipitation begins in these titrations are approximately the same as those at which the precipitation of the respective hydroxides begins, except when the normal tungstates of (chromium and thorium) are formed. Precipitations were obtained on titrating with $Na_2WO_4$ in those salt solutions in which the hydroxides are precipitated in the acid zone. These experiments show at 3:7 and 1:7 tungstates of the different metals are not produced by double decomposition. The precipitation of the various tungstates is directly connected with that of their respective bases (Chem. Abs.).

117. ___. Physicochemical Studies of Complex Acids. Part VI. Precipitation of Molybdates. Jour. Chem. Soc., 1931, pp. 1429-1435.

Potentiometric titrations of metallic-salt solutions with 0.045 M solutions of $Na_2$ - $MoO_4$, $Na_2$ $0,2.33MoO_3$, and $Na_2O.4MoO_3$ were made with a quinhydrone electrode and where possible pH values obtained with a $H_2$ electrode (Chem. Abs.).

**BRODA, E.** See abs. 396.

**BRODSKY, M.** See abs. 221.

**BRODSKY, M. B., AND CUBICCIOTTI, D.** Reactions of Metals With Gases and Salts at High Temperatures. Oxidation of Silicon at High Temperatures. Tech. Rept. 8. See abs. 220.

BROOKS, E. J. See abs. 81.

118. BROWN, A. B., AND REID, E. E. Catalytic Alkylation of Ammonia. Jour. Phys. Chem., vol. 28, 1924, pp. 1067-1076.

The alkylation of ammonia by methyl, ethyl, n-propyl, and n-butyl alcohols, by passing their vapors with ammonia over catalysts at 300°-500°, has been studied quantitatively. The following catalysts, arranged in the order of ascending effectiveness, have been studied: Blue oxide of tungsten, commercial silica gel, alumina, silica gel impregnated with nickel oxide, zirconia, silica gel impregnated with thoria, and special silica gel.

BROWN, F. H., JR. See abs. 228, 231.

119. BROWN, F. H., JR., AND DUWEZ, P. Zirconia-Titania System. Jour. Am. Ceram. Soc., vol. 37, No. 3, March 1954, pp. 129-132.

A phase diagram for the zirconia-titania system is proposed, based on the existence of a hitherto unreported compound, $ZrTiO_4$. Thermal-expansion and X-ray-diffraction experiments were performed on three series of specimens heated at 980°, 1,370°, and 1,760° C., respectively.

BROWN, H. See abs. 284.

BROWN, H. N. See abs. 732.

BROWN, H. R. See abs. 339.

120. BROWN, L. J., AND KATCOFF, S. Search for Short-Lived Yttrium, Zirconium, and Columbium (Niobium) Fission Products. Los Alamos Sci. Lab., AECD-2468, LADC-569, 2 pp.; Jour. Chem. Phys., vol. 17, 1949, p. 505.

The range-separation technique offered no advantages over chemical separation from neutron-irradiated solutions of uranium or plutonium. In the first few runs, when the method of Hume, Ballou, and Glendenin was abbreviated slightly and the final precipitation of zirconium with cupferron was omitted, a new component with a 14-minute half-life appeared in the decay curves. This period vanished when 4 instead of 3 $BaZrF_6$ precipitations were performed and when the precipitation with cupferron was included. Counting was begun 15 minutes after 10-minute bombardments, and no short-lived activity was observed. Thus, no appreciable yield of zirconium isotopes with half-lives between 3 minutes and 17 hours results from fission. (TID-3019.)

BROWNING, J. S. See abs. 761.

121. BRUBAKER, W. M. Stability of Short Arcs in Oxygen, Hydrogen, and Helium. Phys. Rev., vol. 83, No. 5, Sept. 1, 1951, pp. 979-981.

An arc drawn between separating contacts is known to be very unstable, in the absence of oxygen, in the usual power circuit. To study this instability, experiments have been made in which a 4-ampere arc in a 125-volt-d.c. resistive circuit was repeatedly restruck between separating contacts. Various metals were used as cathodes, with spectroscopically pure carbons as anodes in various gases. Data have been obtained showing the dependence of average arc duration after ignition on the cathode material and on the pressure and kind of surrounding atmosphere for a number of metals in oxygen, hydrogen, and helium. Oxygen exhibits an extraordinary stabilizing influence for most metals, whereas in hydrogen the mean life of the arc is generally less than 10 milliseconds, even at atmospheric pressure.

122. BRUES, A. M. Quarterly Report, August to October 1946. Argonne Nat. Lab., MDDC-684, CH-3711, Jan. 14, 1947, decl. Feb. 18, 1947, 67 pp.

The treatment of plutonium ingestion involves the use of zirconium citrate. Intraperitoneal injection of this salt into 200-gm. white female rats, previously given an intravenous injection of plutonium, resulted in markedly raising the urinary excretion of plutonium and changing the distribution of plutonium in the organs. The data on the excretion and distribution of plutonium in zirconium-and sodium citrate-treated animals are summarized in tabular form. The $LD_{50}$ values for thorium and zirconium citrates and for the gluconate of zirconium were determined (TID-3010).

123. BUCKINGHAM, W. D. Design of Zirconium Arc Lamp. Elec. Mfg., vol. 44, 1949, pp. 104, 106, 180, 182, 184.

Investigation of electronic action in earlier enclosed arc lamps led to development of a zirconium open-air concentrated-arc lamp. Developmental methods are discussed.

124. ___. Open-Air Concentrated-Arc Lamp. Jour. Soc. Motion Picture and Television Eng., vol. 54, May, 1950, pp. 567-584.

The open-air concentrated-arc lamp is a new form of the concentrated arc which operates in the open air and does not require any enclosing bulb or protective atmosphere. The light source is a sharply defined, circular spot formed on the end of the electrode by a thin film of incandescent molten zirconium. The lamps can be operated from alternating or direct current and can be made in sizes up to several kilowatts. A 1-kw. lamp operating on alternating current draws 18 amp. at 55v. and produces 3,000 candlepower from a spot 5.4 mm. in diameter whose average brightness is 130 c./sq.mm. The radiation has a continuous black-body type of spectral distribution and a constant color temperature of 3,600° K. Due to a unique operating principle whereby the zirconium metal is constantly renewed from its own products of combustion, the lamps can have lives of several hundred hours. The exhaust products are nontoxic, and the electrodes are replaceable. The lamp is characterized by extreme stability and ease of operation. It is expected to find application in projection, television, flood, and spot lighting and other fields that require intense light sources.

BÜGEL, R. D. See abs. 794.

125. BULLETIN IMPERIAL INSTITUTE. Zircon-Rutile-Ilmenite Beach Sands of New South Wales. Vol. 37, 1939, pp. 428-433.

Deposits of naturally concentrated heavy minerals occur at many places along the coast of New South Wales. Composition and extent of the deposits are outlined.

126. BUREAU OF MINES, MINERAL TRADE NOTES. "Mineral Statistics"- Zircon in Australia. Vol. 38, No. 2, February 1954, pp. 26-27, 32-34, 39-40.

Mineral statistics are given for zircon concentrates in Australia in 1950-52.

127. BURGERS, W. G. On the Process of Transition of the Cubic-Body-Centered Modification Into the Hexagonal-Close Packed Modification of Zirconium. Physica, vol. 1, 1934, pp. 561-586.

The process of transition of the cubic-body-centered modification into the hexagonal-close-packed modification of zirconium can be described by means of a combination of shearing and dilation processes parallel to definite crystallographic directions. The transition has therefore "homogeneous" or "oriented" character.

128. ___. (Roll and Drawn Texture of Zirconium.) Metallwirtschaft Wissenschaft Technik (Berlin), vol. 14, No. 15, Apr. 12, 1935, pp. 285-286.

Rolled zirconium sheet shows the "basal position" (basis plane parallel to the roll plane and a diagonal axis of type I parallel to the roll direction). In drawn zirconium wire a ring-fiber texture is present with the basal plane parallel to the wire axis. An adjustment of a diagonal axis, type I, parallel to this direction could be established under some circumstances only in glowing-hot wires. The textures found are extensively similar to those of magnesium and lead to the conclusion that the translation elements of the zirconium crystal are the same as are found for other hexagonal metals. Reference is made to a possible influence of the transformation process from hexagonal to cubic zirconium upon the sharpening of the texture in case of heating.

129. BURGERS, W. G., AND van AMSTEL, J. J. A. P. Electronoptical Observation of Metal Surfaces. III. Crystal Growth and Allotropic Transition in Zirconium. Physica, vol. 5, No. 4, April 1938, pp. 305-312.

The transition of the hexagonal alpha- into the cubic beta-modification of zirconium was investigated with the aid of the electron microscope. It was observed that, after passing the transition temperature, the more or less equiaxed texture of beta-crystallites was replaced by a lamellar alpha-texture, the direction of the "lamellae" being different in each region, originally occupied by a beta-crystallite. Considered as a whole, the alpha-texture closely resembled the so-called "martensitic" or "Widmanstätten" type of texture, exhibited by martensitic steels and other alloys. On retransformation the original beta-crystallites reappeared, which in their turn could again be transformed into virtually the same lamellar pattern of alpha-crystallites. This behavior may be considered to confirm the theory that the transition is brought about by a homogeneous transformation (by shearing and dilation) of coherent lattice regions from 1 crystalline state into the other, parallel to definite crystallographic directions, the "sense" of the transformation being opposite in successive alpha →beta and beta →alpha transitions, the whole process thus resembling closely the way martensite needles are formed in steel. At temperatures above 1,150° C. the beta-crystallites showed phenomena of crystal growth, whereby the capacity for growth of the individual crystallites could be influenced by insertion of a temporary transition of the metal into the alpha-modification.

130. BURGUS, W. H., KNIGHT, J. D., AND PRESTWOOD, R. J. Radiations of Zirconium$^{97}$ and Niobium$^{97}$. Los Alamos Sci. Lab., AECU-726, LADC-765, 1950, 14 pp.

The radiations of zirconium$^{97}$ and niobum$^{97}$ (columbium) have been examined by beta-ray spectrometry and coincidence counting. The 17.0-hour $Zr^{97}$ has been found to decay to a 60-second isomer of $Nb^{97}$, the latter undergoing isomeric transition to the 75-minute $Nb^{97}$ ground state. The disintergration energies are: $Zr^{97}$, $E\beta = 1.91 \pm .02$ Mev; $Nb^{97m}$, $E\gamma = 0.747 \pm .005$ Mev; $Nb^{97}$, $E\beta = 1.267 \pm 0.2$ Mev; $E\gamma = 0.665 \pm .005$ Mev.

131. BURNS, J. R. Magnesium-Zinc Base Casting Alloys. Wright-Patterson Air Force Base, ATI-44917, Tech. Rept. 5755, Nov. 19, 1948, 77 pp.

The mechanical properties of magnesium-zinc binary alloys were investigated. Heat-treated alloys were capable of developing yield strengths of 23,000 p.s.i. with several percent elongation. The test bars were frequently defective, however, due to an extreme tendency to be microporous. The addition of zirconium resulted in as-cast properties and heat-treated properties that are appreciably superior to any commercially available. Consistently good properties were not obtained, however, owing to microporosity and possibly nonmetallic inclusions.

BURNS, N. See abs. 382.

BURWOOD, T. T. See abs. 179.

132. BUTTERFIELD, J. A. Outgrowths on Zircon. Geol. Mag. (London), vol. 73, 1936, pp. 511-516.

A description of various types of outgrowths of zircon.

## C

133. CAIN, F. M., JR. Simplified Procedure for the Metallography of Zirconium and Hafnium and Their Alloys; Ch. in Zirconium and Zirconium Alloys. Am. Soc. Metals, Cleveland, Ohio, 1953, pp. 176-185; Metal Progress, vol. 63, No. 5, May 1953, pp. 174, 176, 178.

The chemical polish-etch method is a 5-minute metallographic preparation of zirconium and hafnium and their alloys without the aid of mechanical or electrolytic polishing. Specimens to be prepared by this technique are abraded through a 3-0 emery or a No. 600 silicon carbide finish and subsequently dipped in or swabbed with the polishing solution. The resulting microscopic structures can be observed equally well under bright-field or polarized light. A chemically polished specimen is also ideal for stain etching or heat tinting. Remote controlled metallography of irradiated specimens, nondestructive microscopic examination of large sections, macro preparation, bright pickling and reducing dimensional thicknesses are other examples of the versatility of the chemical polish.

CALDWELL, F. R. See abs. 778.

CALKINS, M. C. See abs. 758.

CAMPBELL, I. E. See abs. 3, 393.

134. CARBORUNDUM METALS CO., INC. Zirconium. May 1954, 64 pp.

This booklet presents the story of zirconium. It follows the path of zirconium through its history and development and gives factual information on properties, fabrication, compounds, and chemicals.

CARLSON, R. J. See abs. 683.

CARMODY, W. R. See abs. 463.

CARPENTER, R. L. See abs. 591.

CARRINGTON, W. E. See abs. 11.

135. CARSON, O. A., AND AUSTIN, D. T. Magnesium-Zirconium System. Canadian Min. Jour., vol. 73, April 1952, pp. 70-75.

The magnesium-rich portion of the magnesium-zirconium phase diagram has a peritectic point at 654° C. at 0.42 percent zirconium. The liquidus ascends steeply from this point, probably passing through 0.7 percent zirconium at 900° C., apparently increasing more rapidly above this temperature. The solubility in solid magnesium is 0.34 percent zirconium at 400° C., increasing with temperature to at least 0.43 percent at 600° C. and to over 1.3 percent at the solidus. The zirconium-rich alloys form a solid solution which contains at least 38 percent magnesium. This solid solution undergoes a change at about 1,200° C. at 38 percent magnesium to give an intermediate magnesium-zirconium delta phase. This delta phase may be the compound $Mg_2Zr$, but its exact nature was not established. The remainder of the system consists of a mechanical mixture of the magnesium solid solution and the delta magnesium-zirconium phase. No evidence of the beta-zirconium phase was observed, and it is assumed that magnesium raises the temperature of the transformation.

136. CARTER, A. Sintered Refractory Alloys. Metallurgia, vol. 49, No. 291, January 1954, pp. 8-14.

Increased gas-turbine operating efficiences can only be achieved by using higher operating temperatures, and the search for materials capable of service at such temperatures leads to the study of metal-refractory alloys discussed in this report. In this survey particular reference is made to the alloys based on titanium carbide and a comparison made to alloys based on zirconium carbide.

CARTER, E. See abs. 441.

137. CASTOR, W. S., JR., AND BASOLO, F. Properties of Hydrates. I. Kinetic Identification of Compounds Formed Between Salts and Water. Jour. Am. Chem. Soc., vol. 75, No. 19, Oct. 5, 1953, pp. 4804-4807.

Hydrate compositions can be determined kinetically if the rate of reaction is observed at frequent enough intervals. Either dehydration or hydration procedures can be used, since the method is based primarily upon the heterogeneous character of the reactions. All hydrates known from equilibrium investigations in the regions studied kinetically were found for the greater portion of the systems $CaCl_2H_2O$, $MnCl_2$-$H_2O$, $NiCl_2$-$H_2O$, and $ZrOCl_2$-$H_2O$. In all but the first case, new hydrates were discovered, and reasons for their previous lack of identification are suggested. The method is especially valuable for distinguishing hydrates with similar decomposition pressures and shows promise for those which tend to decompose by some side reaction, such as hydrolysis.

138. CASTOR, W. S., JR., AND BASOLO, F. Properties of Hydrates. II. Olation During Heterogeneous Dehydrations; Structural Formulas for Some Metal Dichloride Hydrates. Jour. Am. Chem. Soc., vol. 75, No. 19, Oct. 5, 1953, pp. 4807-4810.

Compounds in each of the solid systems $MnCl_2.XH_2O$, $NiCl_2.XH_2O$, and $ZrOCl_2.XH_2O$ are characterized by the presence of coordinated hydroxyl groups and water molecules. As a consequence of the structural features deduced here, each of these systems reveals a peculiar dehydration behavior which can be interpreted as a series of olations. The number and kind of these condensations are determined by the number of hydroxyl groups and the geometry of the coordination. Each monomer first yields a diol dimer. The nickel and zirconyl complexes condense again, and the latter does so a third time before olation is complete. Further dehydration then causes a decrease in coordination number from the symmetrical configuration first obtaining to the more usual symmetrical arrangement for each metal ion. The nickel and manganese salts remain chloro complexes, but the zirconyl salt probably does not. A structure suggested for the latter can explain its hydrolysis to 8-coordinated zirconia upon thermal decomposition. The stronger metal-chlorine bonds of the other complexes favor decomposition of anhydrous chlorides.

139. CERAMIC AGE. Hafnium Carbide - Its Properties as a Refractory. Vol. 63, No. 3, March 1954, p. 21.

A brief item on new data on the properties of hafnium carbide in work conducted by the Ceramics Department, Oak Ridge National Laboratory, Oak Ridge, Tenn.

140. CERAMIC INDUSTRY. Zircon Needs Alumina to Opacify. Vol. 51, 1948, p. 60.

This is a discussion of the importance of zirconium oxide in enamels as an economical opacifier and the use of the constituent alumina.

141. ___. Zircon Reduces Crazing Tendency. Vol. 51, 1948, pp. 84, 86.

A brief article on the unusual properties that zircon imparts to some types of pottery bodies.

142. ___. Zirconium Compounds. Vol. 32, February 1939, Repr., 2 pp.

Data are given on the history, properties, and refining of zircon. The use of zirconia in pottery, enamels, and glass is discussed.

143. CERAMICS. Opacifiers - Their Use in the Ceramic Industries. Vol. 6, No. 62, April 1954, pp. 60-62, 64.

Opacification of glazes and enamels has been practiced in the ceramic industry for many years. The demand today lies in a need for opaque glazes and enamels for cheaper pottery and other ceramic applications. Zirconia opacifiers are compared to tin oxide, titania, and cerium oxide. Solubility, firing temperature, acid resistance, colors, grain size, and properties are also covered. The values are given of the refractive indices of some opacifiers compared with that of the glassy material with which they are usually associated.

144. CERAMICS. Zirconium Silicate. Vol. 5, No. 50, April 1953, pp. 67-70.

This article discusses the use of zirconium silicate (zirconite) in foundry molds.

CHAMBERS, D. H. See abs. 167.

CHAMBERS, G. H. See abs. 551.

CHATT, J. See abs. 813.

145. CHEMICAL AGE. Zirconium Carbide Powder. Vol. 67, Oct. 4, 1952, pp. 469-471.

Results are stated on the experiments carried out on the hot pressing of zirconium carbide powders.

146. ___. Zirconium High-Temperature Experiments. Vol. 68, Feb. 7, 1953, pp. 247-250.

Three methods were considered for the direct production of zirconium alloys without using metallic zirconium. The methods were carbon reduction of zirconium oxide in the presence of the metal with which zirconium was to be alloyed; reduction of a zirconium halide in the presence of the alloying metal; and fusion electrolysis. These methods were compared and problems encountered discussed. Consideration was also given to the problems of raw materials, chlorination, losses, and reactions.

147. CHEMICAL AND ENGINEERING NEWS. Increasing Knowledge Will Spur Greater Use of Zirconium and Titanium. Vol. 31, No. 14, Apr. 6, 1953, pp. 1415-1416.

This article reviews the history of the use of zirconium and its potentialities.

148. CHEMICAL ENGINEERING. Direct Process Boosts Yield. Vol. 60, No. 9, September 1953, pp. 158, 160, 161.

The Bureau of Mines in Albany, Oreg., has developed a direct chlorination process for hafnium-free zirconium oxide. This process is discussed, and a comparison is made with the method of chlorination previously used for preparing zirconium carbide.

149. ___. Where You Can Use Zirconium Chemicals. Vol. 61, No. 3, March 1954, pp. 138, 140, 142.

A news item on the rise in demand for zirconium since 1943. Present and potential uses are noted.

150. CHEMISTRY. Rare But Tough Materials Needed. Vol. 27, No. 4, December 1953, pp. 11-12.

A brief discussion of the need for ceramic materials for high-temperature applications.

151. CHEMISTRY AND INDUSTRY. Celtium or Hafnium. Vol. 42, Aug. 17, 1923, pp. 784-788.

This article gives the history of the discovery of hafnium.

CHERNIKHOV., J. A. See abs. 790.

CHESTERS, J. H. See abs. 654.

152. CHUBB, W. Contribution of Crystal Structure to the Hardness of Metals. Jour. Metals, vol. 7, No. 1, January 1955, pp. 189-192.

By measuring the hardness of metals at temperatures just above and just below their allotropic change point, it has been established that crystal structure has a real effect upon the strength of metals. The DPH of cobalt, iron, titanium, uranium, and zirconium has been measured at temperatures up to 1,000° C. It was found that the body-centered-cubic crystal structure is always the softer structure when it is involved in an allotropic transformation. The close-packed and more complex structures are inherently harder and therefore may be expected to be better base materials for high-strength alloys.

153. CLAUSER, H. R. Materials for High-Temperature Service. Materials and Methods, vol. 39, No. 4, April 1954, pp. 117-132.

This report is a survey of materials commonly used at temperatures above 300° F. Included are refractory oxides of zirconium, beryllium, aluminum, thorium, magnesium and calcium. Data are given on melting points, thermal expansion, stress rupture, and creep strength.

CLAUSING, P. See abs. 182.

154. CLAUSSEN, G. F., AND SKEHAN, J. W. Malleable Beryllium. Metals and Alloys, vol. 15, April 1942, pp. 599-603.

This article reports the successful production of malleable beryllium containing small amounts of titanium and zirconium and describes the processing technique employed.

CLEARY, G. See abs. 221.

CLELAND, B. B. See abs. 72, 512.

CLENNELL, J. E. See abs. 586.

CLEWS, F. H. See abs. 659.

COBLE, R. L. See abs. 601.

155. COHEN, B. L. (n,2n) and (n,p) Cross Section. Phys. Rev., vol. 81, No. 2, Jan. 15, 1951, pp. 184-188.

Cross sections of several (n,2n) and (n,p) reactions were measured by bombarding samples with a known flux of neutrons and measuring the induced beta-activity making elaborate corrections for self-absorption of the beta rays. Using the known energy spectrum of the incident neutrons, calculations were made of the cross sections to be expected from Weisskopf's statistical theory, and the agreement was satisfactory; results indicate that level densities in odd-odd nuclei are greater than those in even-even nuclei by a factor of 3±1. Applications of the method to shielding and the use of threshold detectors are discussed.

COHN, S. H. See abs. 300.

156. COLE, D. J., AND WILSON, D. W. Removal of Phosphate as Zirconium Phosphate in Qualitative Analysis. Analyst, vol. 79, No. 936, March 1954, pp. 174-176.

Physical conditions for optimum removal of phosphate by use of zirconium nitrate on a semimicro scale are evaluated, and a recommended procedure is given.

157. COLES, H. L., AND WITHROW, J. R. Zirconium. VII. Corrosion Resistance of Zirconium Alloys. Am. Inst. Chem. Eng., December 1931, pp. 253-263.

A series of tests was made on nickel-zirconium alloys and zirconium-nickel steels to determine their use in corrosion-resistant materials. Results obtained indicated that alloys of nickel and zirconium, together with silicon, aluminum, and iron, offered excellent resistance to the action of hydrochloric and sulfuric acids. Zirconium steels also were found to resist solutions of caustic soda and mixed acids.

158. COLICHMAN, E. L., AND LUDEWIG, W. H. Polarography of Zirconium Salts in Methanol. Anal. Chem., vol. 25, No. 12, December 1953, pp. 1909-1910.

The fundamentals of polarography of zirconium salts are presented in this report.

COLLEY, A. T. W. See abs. 273.

COLLINS, J. F. See abs. 603.

159. COLLINSON, J. A., AND WATSON, W. W. Spectroscopic Isotope Shift in Hafnium I and Hafnium II. Am. Phys. Soc. Bull., vol. 29, No. 4, April 1954, p. 33.

The hyperfine structure of some 70 hafnium I and 20 hafnium II lines in the range 2,870-4,900 A. has been observed. This structure is, in every case, either a line which appears single or a doublet (roughly 0.030-0.050 K), whose components are of the proper relative intensities to be produced by isotopes 178 and 180. The doublets are sometimes in the "negative" sense. In hafnium I, the shifts are consistent with the tentative analysis of that spectrum and indicate that the same electron configuration, presumably $5d^2 6s^2$ of the ground state, is responsible for all 7 low-energy levels. E. Rasmussen, (Naturwiss., vol. 23, 1935, p. 69) reported lambda lambda 4837 and 4800 as single and lambda 4655 as split, while results show lambda 4837 double. In hafnium II, the double electron transition of lambda 3134.72 ($5d6s^2\ {}^2D_{2-1/2}$ - $5d^2 6p\ {}^4G_{2-1/2}$) exhibits structure substantially larger than that in any other line.

160. COMMONS, C. H., JR. Recent Developments in Zirconium Glazes and the Effect of Various Materials on the Results. Bull. Am. Ceram. Soc., vol. 17, No. 11, November 1938, pp. 433-434

Experimental procedures used in the studies of the development of zirconium glazes and the results of the experiments are discussed.

CONKLIN, G. L. See abs. 516.

161. CORDOVI, M. A. Rapid Quantitative Analysis by X-Ray Fluorescence. Steel, vol. 123, No. 5, Dec. 20, 1948, pp. 88-92, 94.

Results of experimental work undertaken to evaluate the industrial merits of an X-ray fluorescence analyzer indicate that a few modifications in present design will bring accuracy within the limits required in routine quantitative chemical analysis of metals.

162. CORK, J. M., LeBLANC, J. M., MARTIN, D. W., NESTER, W. H., AND BRICE, M. K. Nuclear Levels Associated with $Zr^{95}$ and $Nb^{95}$. Phys. Rev., vol. 90, No. 4, May 15, 1953, pp. 579-581.

The half lives associated with radioactive decay and the beta - and gamma-energies of $Zr^{95}$ derived from fission and $Zr^{95}$ derived from neutron captured in enriched $Zr^{94}$ were studied in magnetic spectrometers. $Zr^{95}$ emits 3 beta rays of energy about 910, 405 and 360 kev., each followed by a gamma-transition leading to a radioactive daughter products, $Nb^{95}$. The gamma-energies are 758, 725, and 235.2 kev. The $Nb^{95}$ decays by beta-emission, energy 165 kev., to $Mo^{95}$, with accompanying gamma-energies of 753 and 768 kev. The observed transitions are found to fit a level scheme that is not incompatible with shell theory.

CORYELL, C. D. See abs. 77.

163. COSTER, D., AND HEVESY, G. On the New Element Hafnium. Jour. Soc. Chem. Ind. (England), vol. 42, Mar. 16, 1923, p. 258.

This is a discussion of the metal hafnium and its discovery.

164. COUGHANOUR, L. W., ROTH, R. S., AND DePROSSE, V. A. Phase-Equilibrium Relations in the Systems Lime-Titania and Zirconia-Titania. Jour. Res., Nat. Bur. Standards, vol. 52, No. 1, January 1954, pp. 37-42.

The systems $CaO-TiO_2$ and $ZrO_2-TiO_2$ were studied by means of solid-state reactions and by observing fusion characteristics. The existence of 2 binary compounds in the $CaO-TiO_2$ system was confirmed. One compound was found to exist in the $ZrO_2-TiO_2$ system. This compound ($ZrO_2 \cdot TiO_2$) has been found to have orthorhombic symmetry, with the following parameters at room temperature: a = 4,806 A, b = 5.032 A, c = 5.447 A. Solid-solution development was observed in the $ZrO_2-TiO_2$ but not in the $CaO-TiO_2$ system. From the data obtained, an equilibrium diagram is suggested for each system.

165. COUGHLIN, J. P. Contributions to the Data on Theoretical Metallurgy. XII. Heats and Free Energies of Formation of Inorganic Oxides. Bureau of Mines Bull. 542, 1954, 80 pp.

This publication includes heat and free-energy-of-formation data for zirconium oxide.

CRAIGHEAD, C. M. See abs. 234.

166. CRANDALL, L. A., JR. Absorption of Barium Sulfate and Nonabsorption of Zirconium Dioxide From the Gastrointestinal Tract. Gastroenterology, vol. 13, No. 6, 1949, pp. 513-526.

The absorption of barium after oral administration of barium sulfate to rats was demonstrated by administration of radioactive $Ba^{140}$ as a tracer, followed by determination of the radioactivity of the rat-carcass ash and was confirmed by the spectrographic determination of barium in carcass ash of rats fed ordinary $BaSO_4$. Control studies using zirconium dioxide indicated that no detectable amount of the latter material was absorbed, indicating that the apparent absorption of barium could not be attributed to faulty technique. Certain properties of zirconium dioxide which invite consideration of its use in roentgenologic investigations of the gastrointestinal tract are discussed.

CRANDALL, W. B. Fundamental Properties of Metal-Ceramic Mixtures at High Temperatures. Progress During Period Apr. 1 to May 31, 1951. Periodic Status Rept. 26. See abs. 272.

CRANDALL, W. B., AND LAWRENCE, W. G. Fundamental Properties of Metal-Ceramic Mixtures at High Temperatures. Progress During Period August 1 to September 30, 1950. Periodic Status Rept. 22. See abs. 270.

___. Fundamental Properties of Metal-Ceramic Mixtures at High Temperatures. Progress During Period February 1 to March 31, 1951. Periodic Status Rept. 25. See abs. 271.

167. CREAMER, R. M., CHAMBERS, D. H., AND WHITE, C. E. Electrodeposition of Titanium and Zirconium. Wright Air Development Center, WADC-TR-53-317, December 1953, 23 pp.

Aqueous, nonaqueous, and fused electrolytes have been investigated in an attempt to electrodeposit titanium and zirconium. Aqueous and nonaqueous electrolytes have been found capable only of coplating small percentages of titanium along with another more easily plated metal, such as tin, cadmium or zinc. Fused alkali borate baths were found to give non-adherent, spotty cathode deposits of a titanium boride. Fused halide electrolytes gave powdered metal deposits and a potassium chloride-lithium chloride-titanium (III) chloride electrolyte gave weighable plates on iron, nickel and copper cathodes. Notes on some of the chemical aspects of the investigation are included.

168. CRITES, G. J. Metals of the Future. Instrumentation, vol. 7, No. 2, 1954 (1st Quart.), pp. 14-15.

A brief report on the production and processing of metals, such as zirconium, titanium, vanadium, cerium, and germanium.

169. ___. Vacuum Furnaces for Melting or Processing of Metals. Metal Progress, vol. 63, No. 5, May 1953, pp. 161, 162, 164-166.

The commercial use of vacuum furnaces for processing metals, including zirconium, is covered in this report. Drawings are included for various types of furnaces, such as two-zone horizontal for vacuum heat treatment of electronic parts and fine springs; resistance-heated, movable-retort type; resistance-heated, with bell-type retort and movable furnace shell on fixed base; and the Stokes stationary induction type for melting and casting ingots and complicated shapes. Kroll-process equipment, including furnaces, is in use by the F. J. Stokes Co.

170. **CRONK, G. A.** Zirconium Salts in Prevention and Treatment of Rhus Toxicodendron Dermatitis. Arch. Dermatol. and Syphilol., vol. 66, 1952, pp. 282-288.

Laboratory experiments substantiating the conclusion that certain zirconium salts are beneficial in prophylaxis and treatment of rhus toxicodendron dermatitis.

171. **CRONK, G. A., AND NAUMANN, D. E.** Zirconium Treatment in Ivy Poisoning: Preliminary Investigation. Jour. Lab. Clin. Med., vol. 37, No. 6, June 1951, pp. 909-913.

Zirconium treatment of poison-ivy dermatitis and its effectiveness in 2 experimental cases and 47 clinical cases are reported and discussed, with comment on toxicity of zirconium.

172. **CRYMBLE, C. R.** Relation Between the Absorption Spectra of Metallic Ions and Their Valency. Jour. Chem. Soc., vol. 101, 1912, pp. 266-273.

This report covers an investigation relative to the absorption of light by metals in aqueous solution. The metallic elements may be divided into 2 groups - those of constant valency, the salts of which in aqueous solution transmit the ultraviolet rays, and those of varying valency, the salts of which in aqueous solution absorb ultraviolet light. If the metals are arranged according to their electrode potential, the more electropositive metals are found to be of constant valency and nonabsorptive.

173. **CUBICCIOTTI, D.** Oxidation of Zirconium at High Temperatures. Jour. Am. Chem. Soc., vol. 72, September - December 1950, pp. 4138-4141.

The rate of consumption of oxygen by ductile zirconium metal has been studied in the range 600° to 920°. The oxidation curves were parabolic at all temperatures except 920°, where a small deviation toward linear was observed. The oxidation rates were not affected by changing the oxygen pressure from 0.1 to 20 cm. The temperature coefficient of the parabolic rate constant gave an activation energy of 32 kcal. per mole.

See also abs. 219, 220, 235, 236.

___. Reactions of Metals With Gases at High Temperatures. Oxidation of Zirconium at High Temperatures. Tech. Rept. No. 4. See abs. 218.

**CUBICCIOTTI, D., BRODSKY, M., CLEARY, G., DOWNING, J., AND LEVESQUE, P.** Reactions of Metals With Gases and Salts at High Temperatures. Final Summary of Status of Current Research Problems Not Reported Elsewhere. Tech. Rept. 12. See abs. 221.

**CURTIS, C. E.** See abs. 713.

174. **CURTIS, C. E., DONEY, L. M., AND JOHNSON, J. R.** Some Properties of Hafnium Oxide, Hafnium Silicate, Calcium Hafnate, and Hafnium Carbide. Oak Ridge Nat. Lab. ORNL-1681, Mar. 15, 1954, 36 pp.

The behavior of hafnium oxide was studied, particularly in the temperature range from 1,500° to 1,800° C. Properties of $HfO_2$ at these temperatures and its reactions with $ZrO_2$, $SiO_2$, and CaO are given in terms of lattice and other physical measurements, many of which are new. Monoclinic hafnium oxide is stable to 1,700° C., which is 600° higher than the corresponding inversion temperature of zirconia. Otherwise, $HfO_2$ closely resembles $ZrO_2$ (1) in its lattice dimensions and sintering behavior, (2) in forming a high temperature tetragonal phase closely resembling tegragonal $ZrO_2$, (3) in forming a continuous series of solid solutions with $ZrO_2$, (4) in forming with silica a single compound ($HfO_2$-$SiO_2$) similar to zircon, (5) in forming a carbide, and (6) in uniting with up to 40 percent CaO to form cubic solid solutions; thereafter, a compound CaO-$HfO_2$ appears, which is very similar to the corresponding zirconia compound.

## D

DABBS, J. W. T. See abs. 665.

175. DALTON, J. C., AND THOMSON, S. J. Recent Studies on Iron Meteorites. V. Improved Methods for the Isolation of Uranium and Thorium From Meteorites. Geochim. et Cosmochim. Acta, vol. 5, February 1954, pp. 74-80.

A method is described for the separation of $10^{-8}$g quantities of thorium from solutions of iron meteorites, using 1-(o-arsono-phenyl-azo)-2-naphtol-3:6-disulfonic acid as a precipitant and zirconium as a carrier; uranium present has been shown to remain quantitatively in solution. Solvent-extraction and paper-chromatography methods are described for the recovery of uranium in a sufficiently pure state for fluorimetry. $A^{233}U$ tracer technique, combined with fluorimetry, has allowed reliable estimates to be made of meteoritic uranium.

176. DANIELSON, R. R. Effect of Composition on Properties of Cone 11 Zirconium Silicate-Opacified Glazes. Jour. Am. Ceram. Soc., vol. 29, No. 10, 1946, pp. 282-287.

Studies were made of the effects of magnesium, calcium, barium, strontium, and zinc oxides on the gloss, texture, and opacity of one-fire, zirconium silicate-opacified glazes at cone 11. The opacity was determined with a Hunter multipurpose reflectometer and the gloss was observed visually. Limits for the various fluxes were determined and a practical base glaze formula was developed.

DARDEN, S. E. See abs. 605.

DAS GUPTA, A. K. See abs. 192.

177. DATSKO, S. C. Corrosion of Metals in High-Temperature Water at 500° F. and 600° F. February 1949 - July 1953, Argonne Nat. Lab., ANL-5354, Oct. 4, 1954, 203 pp.

The corrosion behavior of a series of structural materials, which included zirconium alloys, was investigated. Several water treatments not generally used were employed in an attempt to minimize corrosion, and the effects of these treatments are discussed. Several materials, such as the 300-series stainless steels and certain types of zirconium, have been found to be satisfactory at both 500° and 600° F. in all environments in which they were tested. Other materials were found to be satisfactory under specific conditions. At 500° F. the addition of over 50 cc. of hydrogen per liter of water permits the widest selection of materials.

178. DATTA, S. K., AND BANERJEE, G. Estimation of Thorium by Organic Reagents. Part III. Use of 2:4-D in the Separation of Thorium From Zirconium, Titanium and Iron and Their Co-Determinations. Jour. Indian Chem. Soc., vol. 31, No. 10, October 1954, pp. 773-778.

2:4-D can separate thorium completely from ferrous iron and titanium solutions. But as this reagent forms quantitative precipitates of both ferric iron and zirconium, workable methods for their separation and codeterminations with the help of the reagent have been developed. A process for separating and estimating iron (ic), zirconium, thorium, and titanium, when present in a mixture, has also been dealt with.

DAVEY, W. P. See abs. 222.

179. DAVIDSON, H. W., AND BURWOOD, T. H. High-Temperature, High-Vacuum Furnace. Engineering, vol. 177, No. 4591, Jan. 22, 1954, pp. 106-108.

The sintering of carbides and other refractories and the specialized heat treatment of zirconium, titanium, tantalum, and other metals are some applications for a high-vacuum furnace. This report gives details of such a furnace.

180. DEAN, R. S., AND SILKES, B. Metallurgical Research Program of the

Bureau of Mines Relating to the Nonferrous Metals. Bureau of Mines Rept. of Investigations 4064, 1947, 22 pp.

The metallurgical research program of the Bureau of Mines on nonferrous metals included development of a process for producing ductile zirconium metal from zircon sand. This process is covered briefly in the report.

181. DE BOER, J. H. Zirconium. Ind. Eng. Chem., vol. 19, No. 11, November 1927, pp. 1256-1259.

The method for preparing very pure ductile zirconium is described; it starts with the ore and gives the purification of zirconium salts. Pure ductile zirconium is prepared by decomposing the tetraiodide vapor by means of a heated filament. A number of physical properties, such as melting point, specific gravity, electrical resistivity, etc., have been determined.

182. DE BOER, J. H., CLAUSING, P., AND FAST, J. D. Alpha-Beta Transition With Mechanically Treated and With Untreated Zirconium. Rec. trav. chem., vol. 55, 1936, pp. 450-458.

In 1926 a change in modification of zirconium at higher temperatures was discovered by Zwikker. No sharp transition temperature was found, although a transition range of about 300° C. was indicated. Later determinations by other methods resulted in the discovery of a sharp transition temperature. These later determinations were carried out with undeformed zirconium rods, whereas the resistance measurements of Zwikker were carried out with wires, which had been prepared from such rods. It has now been shown, by means of resistance measurements on zirconium rods, which had previously undergone varying treatment, that the indefinite character of the alpha→beta transition in resistance measurements of zirconium wires may be ascribed, not to the deformation itself, but to the heating in the air at different stages of the deformation. The temperature of the transition alpha→beta zirconium was found to be 865° ± 10° C., in good agreement with the value determined by Vogel and Tonn by another method. In the case of beta zirconium, total radiation is proportional to $T^{4.7}$.

183. DE BOER, J. H., AND FAST, J. D. Alpha-Beta Transition in Zirconium in the Presence of Hydrogen. Rec. trav. chim., vol. 55, 1936, pp. 350-356.

Hydrogen may be dissolved in alpha as well as in beta zirconium; in both modifications the solubility decreases with rising temperature. If alpha zirconium is transformed into beta zirconium with rising temperature in the presence of hydrogen, hydrogen is taken up, while during cooling beta zirconium changes over into alpha zirconium and gives off hydrogen. The transition from beta zirconium to alpha zirconium seems to be a necessary condition for rapid solution of hydrogen during cooling of zirconium wire.

184. DE BRETTEVILLE, A. P., JR. Threshold Field and Free Energy for the Antiferroelectric-Ferroelectric Phase Transition in Lead Zirconate. Phys. Rev., vol. 94, No. 5, June 1, 1954, pp. 1125-1128.

Sawaguchi and Kittaka obtained the threshold field of $PbZrO_3$ (that field necessary to change the antiferroelectric to the ferroelectric phase) below the Curie temperature. The free-energy difference is the difference between the area under the ferroelectric portion of the curve and that under the antiferroelectric portion. An expression for free-energy difference has been obtained as a function of voltage by eliminating the temperature parameter. This experimental relationship is compared with the theoretical expression which involves the product of the constant spontaneous polarization ($16 \times 10^{-6}$ coulomb/cm$^2$. in the ferroelectric phase), the threshold voltage and the molar volume (43 cm$^3$.). The free energy so calculated is small; of the order of 4 cal./mole at 25 kv./cm. Equations are given for calculating the threshold field-strength and free-energy difference as functions of temperature. The equation for threshold field-strength resembles the Clapeyron-Clausius equation, with field strength analogous to pressure and spontaneous polarization analogous to volume. The threshold voltage versus the downward shift of the Curie temperature is in good agreement with the experimental results of Sawaguchi and Kittaka.

DECKER, B. F. See abs. 423.

185. DEEM, H. W. Thermal Conductivity and Electrical Resistivity of Hafnium. Battelle Mem. Inst. BMI-853, July 14, 1953, 12 pp.

Thermal-conductivity measurements by a steady-heat-flow method and electrical-resistivity measurements by a voltage-drop method were made on hafnium containing about 2 weight-percent zirconium. The measured thermal conductivities, C, in watts/(cm.) were 0.220 at 100° C., 0.210 at 300° C., and 0.205 at 500° C. The electrical resistivities in microhm-cm. were 40.6 at 50° C. and 60.1 at 200° C. Based on the resistivity at 0° C., the temperature coefficient of resistance is 0.00382/C.

186. DE HAAS, W. J., AND VAN ALPHEN, P. M. Change in Resistance of Graphite, Thorium, Titanium-Zirconium between 20°.4 K. and 1°.1 K. Proc. Roy. Acad. Sci. (Amsterdam), vol. 34, 1931, pp. 70-74.

Resistance measurements were made on titanium-zirconium crystals precipitated from the gaseous states. Typical behavior patterns are given.

187. DE HAAS, W. J., AND VOOGD, J. Change of the Electric Resistance of Pure Hafnium and Zirconium Between 1.3° K. and 90° K. Proc. Roy. Acad. Sci. (Amsterdam), vol. 32, 1929, pp. 707-709.

Results are given of measurements of the electric resistance of pure hafnium and zirconium at temperatures between 1.3° and 90° K. It was determined that hafnium and zirconium belong to the non-supraconductors.

188. DE LAUNAY, J. On the Isotope Effect in Superconductors. Phys. Rev., vol. 79, 1950, pp. 398-399.

For isotopes of the same element, A $1/2T_c$ = constant, when atomic weight and $T_c$ the critical temperature above which superconductivity cannot exist. Since the ratio of $T_c$ to Debye-characteristic temperature is approximately constant for aluminum, cadmium, gallium, hafnium, titanium, zinc, and zirconium, these elements appear to have similar electron-ion properties insofar as the dominant wavelength is involved.

DE PROSSE, V. A. See abs. 164.

DER MATEOSIAN, E. See MATEOSIAN, E. DER.

189. DETWEILER, J. C. Jacksonville Plant Produces Titanium From Beach Deposit. Min. Eng., vol. 4, No. 6, June 1952, pp. 560-562.

This article covers the development and progress of the Jacksonville plant and describes the operational procedures.

DEUTSCH, M. See abs. 300, 733.

DEWDNEY, J. W. See abs. 279.

190. DEY, A. K. Economic Utilization of India's Mineral Raw Materials and Their Byproducts. Indian Minerals, vol. 8, No. 2, April 1954, pp. 65-77.

This report is a survey of India's mineral resources, including the byproduct of black-sands zircon. Production of zircon commenced in India in 1922 and from 1922 to 1946 over 38,000 tons was exported.

DHAR, N. R. See abs. 282, 306, 636, 637, 638, 720.

191. DHAR, N. R., AND GORE, V. Change of Precipitating Concentrations of Electrolytes With the Purity and

Temperature of Some Hydroxide Sols. Jour. Indian Chem. Soc., vol. 6, 1929, pp. 31-43.

Sols of ferric hydroxide, chromic hydroxide, and zirconium hydroxide of different degrees of purity were prepared, and it was shown that the ratio of the precipitating concentrations of uni-, bi- and tri-valent ions decreases considerably as the purity of the sol is increased. It has been shown that the ratio of the precipitation concentrations of uni- and bi-valent ions on sols of stanic hydroxide, zirconium hydroxide and ceric hydroxide decreases as the temperature of coagulation is increased.

192. DHAR, S. K., AND DAS GUPTA, A. K. Colorimetric and Volumetric Estimation of Zirconium. Jour. Sci. Ind. Res. (India), vol. 11B, November 1952, pp. 500-501.

This is a brief note on the possible use of oxalohydroxamic acid as a reagent for the estimation of zirconium in minerals.

DICKERSON, R. F. See abs. 683, 684.

193. DINEEN, D. E., AND BENSON, N. D. Cast and Extruded Magnesium Alloys. Metal Industry (London), vol. 71, No. 6, Aug. 8, 1947, pp. 103-105.

Low-temperature tests were carried out on samples supplied by Magnesium Elektron, Inc. Details are given of analyses and casting conditions. The results are given for impact and tensile tests at room temperatures.

DI PIETRO, W. O. See abs. 582.

194. DI PIETRO, W. O., AND FINDLAY, G. R. Preparation of Ductile Zirconium. Progress Report for January 1949. Nat. Res. Corp., AECD-3561, NR-7, Feb. 10, 1949, 5 pp.

Plans are given for initiating this project. Experimentation will begin with experimental apparatus for the continuous casting of zirconium from vacuum and on the dissociation of zirconium halides. Final report in this series included in Zirconium Bibliography, vol. 1, No. 354.

195. ___. Preparation of Ductile Zirconium. Progress Report for February 1949. Nat. Res. Corp., AECD-3562, NR-8, Mar. 15, 1949, 9 pp.

Discusses preliminary steps in design of dissociation and casting equipment. Experiments on electrode design for dissociation equipment were conducted, and it was shown that copper-tipped, water-cooled electrodes probably would be satisfactory. Additional experimental work is necessary before dissociation equipment can be designed. Design of continuous casting equipment is near completion.

196. DI PIETRO, W. O., FINDLAY, G. R., AND MELLEN, G. L. Preparation of Ductile Zirconium. Progress Report for March 1949. Nat. Res. Corp., AECD-3563, NR-9, May 5, 1949, 7 pp.

Approval was secured for continuous casting equipment, and construction was begun. Installation of arc generators and associated controls was mainly completed. The decomposition furnace was altered to allow zirconium tetrahalide to be fed into the arc plasma region. The detonating properties of zirconium powder were discussed.

197. ___. Preparation of Ductile Zirconium. Progress Report for April 1949. Nat. Res. Corp., AECD-3564, NR-10, May 13, 1949, 7 pp.

This report covers progress in fabricating continuous casting apparatus and its assembly.

198. ___. Preparation of Ductile Zirconium. Progress Report for May 1949. Nat. Res. Corp., AECD-3565, NR-11, July 8, 1949, 14 pp.

The decomposition of zirconium tetrachloride showed no promising results. Work was begun on the production of the tetraiodide. Design weaknesses were determined for the decomposition furnace by operating it, and a modified unit was constructed. Preliminary tests were made on the compatibility of various elements of the partly assembled casting unit at high temperature.

199. DI PIETRO, W. O., FINDLAY, G. R., AND MELLEN, G. L. Preparation of Ductile Zirconium. Progress Report for June 1949. Nat. Res. Corp., AECD-3566, NR-12, July 26, 1949, 9 pp.

Work was initiated on the tetraiodide. Preliminary runs with $ZrI_4$ indicated potential ultimate success with this compound. A small-scale production operation for making $ZrI_4$ was begun. The final phases of the fabrication of the casting unit were completed, and initial runs with stainless-steel ingots were begun.

200. ___. Preparation of Ductile Zirconium. Progress Report for July 1949. Nat. Res. Corp., AECD-3567, NR-13, Aug. 10, 1949, 18 pp.

Additional runs were carried out on dissociation of $ZrI_4$, and it was demonstrated that weight increases observed in the dissociation chamber were due to collection of zirconium metal. A series of runs on stainless ingots was made in the casting unit, and ingot cooling and electrode design were studied in relation to melting contours in preparation for attempts at ingot withdrawal.

201. ___. Preparation of Ductile Zirconium. Progress Report for August 1949. Nat. Res. Corp., AECD-3568, NR-15, Sept. 9, 1949, 8 pp.

Plans were made for constructing a new apparatus for research on arc dissociation of zirconium iodide. The equipment for continuous casting of zirconium was modified to prevent failure of electrodes. The mechanism for feeding powder was tested and modified slightly on the basis of these tests. Attempts were made to feed and melt stainless steel powder for test purposes, but this approach was abandoned since the residual magnetism of the heat-treated powder was still sufficient to cause jamming of the feed mechanism. The ingot-withdrawal apparatus was assembled, and final preparations were made for tests of zirconium powder.

202. FINDLAY, G. R. Preparation of Ductile Zirconium. Summary of Thermodynamic Data. Nat. Res. Corp., AECD-3569, NR-16, Sept. 16, 1949, 9 pp.

A summary of thermodynamic calculations for zirconium halides is given. Data indicate that the iodide is the most promising of the halides for arc dissociation and that good recoveries of zirconium should be obtainable provided dissociation is carried out at reduced pressure.

203. DI PIETRO, W. O., FINDLAY, G. R., AND STAUFFER, R. A. Preparation of Ductile Zirconium. Progress Report for September 1949. Nat. Res. Corp., AECD-3570, NR-17, Oct. 10, 1949, 11 pp.

A report was submitted describing the apparatus proposed for further dissociation experiments, and approval for necessary construction was requested. While awaiting approval, detailed designs were completed, and some experimental work necessary for this design was carried out. The casting equipment was modified in accordance with experimental work for casting zirconium. The apparatus was tested, and it was found possible to form and withdraw an ingot of zirconium.

204. ___. Preparation of Ductile Zirconium. Progress Report for October 1949. Nat. Res. Corp., AECD-3571, NR-18, Nov. 10, 1949, 9 pp.

Construction of new equipment for dissociation experiments was begun. The equipment for making tetraiodide was completed, and the dissociation unit proper was being assembled at the end of the month. Several experiments were carried out in the continuous casting equipment. The results were promising but indicated the need for more operating controls.

205. DI PIETRO, W. O., FINDLAY, G. R., AND STAUFFER, R. A. Preparation of Ductile Zirconium. Progress Report for November 1949. Nat. Res. Corp., AECD-3572, NR-19, Dec. 10, 1949, 8 pp.

Apparatus for preparing $ZrI_4$ was put into operation and found to work satisfactorily. Apparatus for dissociating $ZrI_4$ was completed, and one run was carried out. Results were not satisfactory and were not comparable to preliminary tests. The cause of the variance is being investigated. The casting apparatus was supplied with a more adequate control system. Several runs were attempted, and the results are given.

206. ___. Preparation of Ductile Zirconium. Progress Report for December 1949. Nat. Res. Corp., AECD-3573, NR-20, Jan. 10, 1950, 11 pp.

Additional runs in the dissociation apparatus were carried out in an effort to eliminate equipment difficulties and permit uniformity of operation from one run to another. Further attempts were made to devise controls for the continuous casting apparatus. Difficulty from spattering of zirconium powder during casting interfered with this objective. Degassed zirconium chips were prepared to eliminate this difficulty. One run was made on this material, and control was improved to the extent that ingot cracks were substantially eliminated. Some feeding difficulties which were encountered are being remedied by minor equipment changes.

207. DI PIETRO, W. O., FINDLAY, G. R., AND MOORE, J. H. Preparation of Ductile Zirconium. Progress Report for January 1950. Nat. Res. Corp., AECD-3574, NR-21, Feb. 10, 1950, 8 pp.

A new feeder chute on the continuous casting apparatus and the use of outgassed zirconium chips resulted in a stable arc and a quiet pool. Ingots up to 9-1/2 inches in length were made, and some correlation between tension on the ingot and the "necking" effect was determined. Conversions of zirconium iodide to zirconium in the arc dissociation-apparatus ran from 41 to 48.2 percent, with a maximum of 474 grams of metal produced in 4 hours.

208. ___. Preparation of Ductile Zirconium. Status Report for February 20, 1950. Nat. Res. Corp., AECD-3575, NR-22, Feb. 21, 1950, 24 pp.

The status of the continuous casting process for zirconium and the arc-dissociation process for zirconium tetraiodide are reviewed.

209. ___. Preparation of Ductile Zirconium. Progress Report for February 1950. Nat. Res. Corp., AECD-3576, NR-23, Mar. 10, 1950, 12 pp.

A tungsten-tipped electrode has been used in the continuous-casting arc furnace for a 25-minute period, during which a 12-inch length of ingot was made. Thermocouple junctions within the mold wall have been improved to give mold zone temperature. A total of 10 iodide dissociation runs have been conducted, using feed rates of 0.62-22.7 pounds $ZrI_4$ per hour, with attendant conversion efficiencies of 97.7-16.4 percent and zirconium yields of 255-41.2 gm. per hour. A curve expressing these data for an arbitrarily selected set of conditions is presented.

DIVEN, B. C. See abs. 335.

210. DOAN, J. P., AND ANSEL, G. Some Effects of Zirconium on Extrusion Properties of Magnesium-Base Alloys Containing Zinc. Trans. AIME, vol. 171, 1947, pp. 286-303.

The magnesium-rich corner of the magnesium-zinc-zirconium system has been studied in the composition range 0 to 7 percent zinc and 0 to 1 percent zirconium with regard to extrudability, tension, and compression properties, metallography, and toughness. Zirconium has the outstanding effect of greatly increasing the extrudability of magnesium-zinc alloys, particularly those of high zinc content. This effect is shown to be related to the increase in the solidus temperature of these alloys due to zirconium. Tensile and compressive properties in the wrought state are critical functions of composition and extrusion speed. Strengths increase with both zinc and zirconium contents and decrease with increasing extrusion speed. In the composition ranges 3 to 6 percent zinc and 0.5 to 1.0 percent zirconium and at 5 to 25 feet per minute extrusion speed, exceptional combinations of compression yield strength and extrusion speed are possible. Unusually fine grain size in the wrought state accounts for the high strengths and the high ratio of compression to tension yield strength of which these alloys are capable. It is hypothesized that wrought grain-size control results from the numerous sharp solid-solution gradients known to exist in the cast state and intensified by extrusion. Zirconium has the dual role of creating the required cast structure and inhibiting its loss by diffusion during preheating and hot-working. In spite of simple tensile ductility and strength comparable with that of the present high-strength, magnesium-base, extrusion alloy (O-$_1$HTA), magnesium-zinc-zirconium extrusions are vastly tougher and less notch sensitive. In view of the characteristics reported, magnesium-zinc-zirconium alloys appear destined for commercial use as extrusion alloys.

DOBSON, E. L., GOFMAN, J. W., JONES, H. B., KELLY, L. S., AND WALKER, L. J. Studies With Colloids Containing Radioisotopes of Yttrium, Zirconium, Columbium, and Lanthanum. II. Controlled Selective Localization of Radioisotopes of Yttrium, Zirconium, and Columbium in the Bone Marrow, Liver, and Spleen. See abs. 297.

211. DODD, A. E. Recent Developments in High-Temperature Refractory Materials. Jour. Inst. Fuel, vol. 23, May 1950, pp. 144-147.

In a number of industries, such as steel, gas, nonferrous metals and glass, the speed of the chemical reactions involved has been increased in the last 30 years by raising the temperature. The resultant increase in the rate of slag attack on the furnace lining has emphasized the need for improved high-temperature refractories. These are now being provided as the outcome of experiments described in this paper.

212. DOMAGALA, R. F., AND MCPHERSON, D. J. System Zirconium-Oxygen. Jour. Metals, vol. 6, No. 2, February 1954, pp. 238-246.

Iodide zirconium was combined with calculated amounts of $ZrO_2$ or master alloys and arc-melted. Annealing treatments were carried out at 21 temperature levels. Metallographic examination of the heat-treated specimens permitted construction of the binary-phase diagram from zirconium to $ZrO_2$. Oxygen additions to zirconium raise the transformation temperature, as well as the melting point. Features of the diagram include the peritectic formation of beta, the formation of alpha directly from the melt, an intermediate phase $ZrO_2$ with a range of homogeneity, and a eutectic between alpha and $ZrO_2$.

DONEY, L. M. See abs. 174.

DONOGHUE, J. J. See abs. 581.

213. DOW CHEMICAL CO. Development of High-Strength Sheet From Powder Fabricated Magnesium Alloys Containing Zinc, Zirconium, and Aluminum. 3d Quart. Rept., Oct. 15, 1951 to Jan. 15, 1952; AD-11553, Mar. 15, 1952, 21 pp.

Investigation of fabrication variables revealed that good properties and rollability are obtained by rolling ZK30 and ZK60 plus A20 powder extrusions to gage in one heat below the recrystallization temperature. Illustrative properties of ZK60 + 1A20 rolled to gage in one heat are listed below:

| Rolling range, °F. |
|---|
| <500 - 800 |

Hot-rolled, 600° F. - 1 heat
1,000 p.s.i.

| %E | TYS | CYS | TS | NBE |
|---|---|---|---|---|
| 5 | 49 | 40 | 58 | 5 |

214. **DOW CHEMICAL CO.** Development of High-Temperature Magnesium Alloys With Specified Neutron Cross Section. Quart. Status Rept., Dec. 1, 1950 - Mar. 1, 1951, Rept. 15035; ATI-122340, Mar. 20, 1951, 27 pp.

The addition of zirconium to sand-cast magnesium-thorium alloys markedly reduces the grain size of these alloys and increases the tensile properties at all temperatures. At the same time, zirconium improves the creep resistance at 400° and 500° F. and has little or no effect on the creep resistance at 600° F. The result of these changes is that magnesium-thorium-zirconium alloys exhibit the best combination of static properties and creep resistance up to 600° F. of any magnesium alloy system yet investigated. The tensile properties of extruded magnesium-thorium alloys are not changed by the addition of zirconium. However, preliminary tests indicate the creep resistance, particularly at 500° and 600° F., is markedly improved.

215. ___. Second Quarterly Report Office of Air Research for Period September 1, 1951, to December 1, 1951 - Phase I, Part 1 Room-and Elevated-Temperature Properties of Magnesium Alloys Containing Thorium Rare Earths and Zirconium; Part 2 An Evaluation of Foundry Characteristics and Static and Dynamic Properties of EK21D and JK31A Alloys. Repts. 15507 and 15646, AD-5395, ATI-143770, Dec. 15, 1951, 20 pp.

Part 1: The following alloys have been investigated: Magnesium-zirconium-1, 2, and 3 percent thorium, with 1-percent additions of Di, Ce/Di (50/50), mischmetal and cerium-free MM; 2 and 3 percent lanthanum, with magnesium-1 thorium-zirconium; 0.5 and 1 percent manganese with magnesium-1 thorium and magnesium-2MM-1 thorium; and 2 and 4 percent zinc with magnesium-1, 2 and 3 percent thorium-zirconium. The creep resistance of cast T6 magnesium-2MM-1 thorium-1 manganese alloy is exceptional. At 500° and 600° F. the creep properties are superior to those of magnesium-thorium-zirconium alloys. Ductility at room temperature is low due to large equiaxed grains. The magnesium-thorium manganese alloys have high creep resistance at 600° F., but all other properties are lowered by the columnar grain structure. An outstanding combination of room- and elevated-temperature properties are attained in extruded T5 magnesium-zinc-thorium-zirconium alloys. The 1-percent rare-earth additions improve the room- and elevated-temperature properties of magnesium-thorium-zirconium alloys up to 500° F. The loss in creep resistance at 500° and 600° F. is not as pronounced in the 1-percent rare-earth additions as in the 2- and 3-percent additions. The level of creep resistance at 500° and 600° F., however, is considerably lower than that of the magnesium-thorium-zirconium alloys. Strength properties of the 1-percent additions are slightly lower than the higher rare earth additions at all thorium levels.

Part 2: The procedure used in evaluating the 2 sand-casting alloys EK21D-T6 and JK31A-T6 is presented. ED21D-T6 is an alloy of magnesium - 2 percent didymium + 0.6 percent zirconium in the heat treated and aged condition. JK31A-T6 consists of magnesium + 3 percent thorium + 0.7 zirconium in the heat-treated and aged condition. Four castings have been poured in the production foundry in each of the 2 compositions. The analysis of the melts from which the castings were poured are presented. The thorium content in 2 of the castings is below that desired.

**DOWNING, J.** See abs. 221.

**DRALEY, J. E.** See abs. 681.

216. **DRAVNIEKS, A.** Action of Hot Ionized Gases Upon Zirconium and Copper. Jour. Phys. and Colloid Chem., vol. 55, No. 4, April 1951, pp. 540-549.

By measuring changes in electrical resistance the relative reaction rates of zirconium at 986° C. with low-pressure nonionized and ionized oxygen, air, water vapor, carbon dioxide, carbon monoxide, nitrogen containing 0.5 percent oxygen, ethane, and technical helium were studied. In some cases, an acceleration and, in others, a retardation of the reaction upon ionizing the gas was observed. The retardation may be explained by a clean-up effect on the surface of the metal or reaction film by the nonreacting components of the gas phase. The oxidation in water vapor seems abnormally rapid as compared with the oxidation in oxides of carbon or in nitrogen with 0.5 percent oxygen. The oxidation of copper in both forms of gases was studied at 750° C. The ionization of carbon dioxide causes a slow oxidation of copper, which proceeds according to the parabolic law. Copper does not undergo oxidation in nonionized and ionized carbon monoxide. A method of recording continuously the progress of the oxidation of metal strips is described.

217. DRAVNIEKS, A. Reactions of Metals With Gases at High Temperatures. Reactions of Zirconium and Copper With Several Ionized Gases. Illinois Inst. Technol., Tech. Rept. 2, August 1949, 10 pp.

The reaction rates of zirconium at 986° C. with low-pressure nonionized and ionized oxygen, air, water vapor, carbon dioxide, carbon monoxide, nitrogen with 0.5 percent oxygen, technical helium, and ethane were studied conductometrically. In some cases an acceleration, in others a retardation of the reaction upon ionizing the gas was observed. The retardation may be due to a cleanup effect on the surface of the metal or scale by the nonreacting components of the gas phase. The oxidation in water vapor seems abnormally fast as compared with the oxidations in carbon oxides. The oxidation of copper in nonionized and ionized gases at 750° C. was studied. The thermodynamically possible oxidation of copper in nitrogen with 0.5 percent oxygen was not observed. Ionization of carbon dioxide causes slow parabolic oxidation of copper but carbon monoxide does not. A method of continuous recording of the progress of oxidation of metal strips at high temperatures is described.

218. CUBICCIOTTI, D. Reactions of Metals With Gases at High Temperatures. Oxidation of Zirconium at High Temperatures. Illinois Inst. Technol., Tech. Rept. 4, November 1949, 10 pp.

The present investigation of the oxidation was made to study the reaction in the intermediate temperature range of 600° to 900° C. The 2 types of reactions, 1 occurring at low temperatures, the other at high temperatures, indicate that at some intermediate temperature there must be a point at which both reactions occur simultaneously.

219. LEVESQUE, P., AND CUBICCIOTTI, D. Reactions of Metals With Gases at High Temperatures. Reaction Between Oxygen and Thorium. Illinois Inst. Technol., Tech. Rept. 7, June 1950, 10 pp.

A comparison of the rate of oxidation of thorium with those of zirconium and titanium is not simple since the last two obey a different oxidation law from that of thorium. However, thorium reacts more rapidly with oxygen than zirconium or titanium. At 400° C. in 30 minutes, a square centimeter of thorium reacts with 0.14 mg. of oxygen while zirconium reacts with 0.035 mg. and titanium with 0.012 mg. Thus the order of oxidation rates of the metals of group IV B in increasing rates is titanium, zirconium and thorium. The rate of consumption of oxygen gas by thorium metal has been studied in the temperature range 350° to 700° C. In the oxidations above 450° C., the temperature of the sample was found to rise considerably above the temperature of the furnace. Below 450° C. the oxidations were found to be isothermal, and the oxidation curves were linear in time. From 350°

to 450° C. the rate constants for the linear oxidation were measured and the energy of activation calculated to be 22 kcal. per mole.

220. **BRODSKY, M. B., AND CUBICCIOTTI, D.** Reactions of Metals With Gases and Salts at High Temperatures. Oxidation of Silicon at High Temperatures. Illinois Inst. Technol., Tech. Rept. 8, August 1950, 8 pp.

The oxidation of silicon was studied in order to compare it with the oxidations of other metals of group IV of the periodic table. The metal was found to oxidize very slowly even at high temperatures. At 950° C. the oxidation followed the parabolic law; from 1,015° to 1,120° C. it obeyed a logarithmic law. The energy of activation of the logarithmic oxidation was 29 kcal. per mole. An explanation of the logarithmic nature of the oxidation is attempted in view of the vitreous nature of the oxide formed. Comparison can be made with titanium, zirconium and thorium which have already been investigated.

221. **CUBICCIOTTI, D., BRODSKY, M., CLEARY, G., DOWNING, J., AND LEVESQUE, P.** Reactions of Metals With Gases and Salts at High Temperatures. Final Summary of Status of Current Research Problems Not Reported Elsewhere. Illinois Inst. Technol., Tech. Rept. 12, June 1951, 15 pp.

An apparatus for measuring the solubility of hydrogen in metals has been built. Results obtained on pure zirconium check with literature values. The change of enthalpy has been calculated for the transition from alpha zirconium saturated with hydrogen to beta zirconium saturated with hydrogen. Zirconium tetraiodide has been prepared and a freezing point is being determined. Attempts will be made to determine freezing points of the salt equilibrated with metal.

## D

222. **DROPHY, D. H., AND DAVEY, W. P.** Separation of Zirconium and Hafnium. Am. Phys. Soc., vol. 25, 1925, pp. 882-883.

A brief note on the separation of zirconium and hafnium. It has been shown that zirconium citrate is insoluble in pure water while hafnium citrate is quite soluble.

**DRYDEN, C. E.** See abs. 3.

**DUCKWORTH, H. E.** See abs. 279.

**DUCKWORTH, W. H.** See abs. 508, 509, 740.

**DUFFIELD, R. B.** See abs. 335.

223. **DUKE, F. R., AND BREMER, R. F.** On the Existence and Relative Stability of Hafnium Peroxide. Contribution No. 134. Iowa State Coll. Jour. Sci., vol. 25, 1951, pp. 293-294; Ames Lab., Iowa State Coll., AECU-1101, undated, 3 pp.

It has been reported that the hafnium compound corresponding to alkali-soluble peroxyzirconate differs from its analog in solubility and that the acid peroxysulfate of zirconium exists, whereas its hafnium analog does not. To a solution of 25 gm. (98.67 percent $ZrCl_4$, 1.33 percent $HfCl_4$) in 100 ml. $H_2O$ were added 50 ml. of 30-percent $H_2O_2$ and $NH_4OH$ until a distinct odor of $NH_3$ persisted. Hydrous zirconium peroxide precipitated quantitatively. The filtered precipitate was partially dissolved in 300 ml. of 0.2M KOH containing 25 ml. of 30-percent $H_2O_2$. The solution was heated at 90° to 100° for 2 to 3 minutes, when ~10 percent of the original metal was precipitated. Spectrographic analysis showed that 1.29 percent of the metal in the precipitate was hafnium. Fractionation by slow precipitation on standing and gradual addition of $CH_2O$ produced samples whose extreme range of content was 1.09 to 1.47 percent hafnium. Since the analysis has an accuracy of +0.2 percent, there is little difference between the peroxy compounds of hafnium and zirconium. A test using 97 percent $HfCl_4$ showed that zirconium need not be present to solubilize hafnium (TID-3010).

224. DuMOND, T. C. Annual Materials Engineering Review and Forecast. Materials and Methods, vol. 39, No. 1, January 1954, pp. 117-121.

Reviews the titanium and zirconium industry in 1954 and forcasts future potentialities.

DUNKERLEY, F. J., MILLS, G. J., AND PLEDGER, F. Preparation of Single Crystals of Beryllium and Zirconium; Study of Mechanical Properties and Recrystallization and Grain Growth Characteristics of Beryllium and Zirconium. Project Status Rept. Oct. 1, 1949, to Jan. 1, 1950; NP-1420. See abs. 105.

___. Preparation of Single Crystals of Beryllium and Zirconium; Study of Mechanical Properties. Part II. Recrystallization and Grain Growth Characteristics of Beryllium and Zirconium. Periodic Status Rept. Jan. 1, 1950, to Apr. 1, 1950; NP-1654. See abs. 106.

225. DUTTON, C. A., AND WAGNER, B. F. Effect of Zirconium Oxide in Glasses and Enamels. Ceram. Ind., vol. 24, January 1935, pp. 88, 109.

Reviews the properties of zirconium oxide and its effect in use in glasses and enamels. The first part of this series deals with titanium and zirconium compounds and their application in enamels.

226. ___. Titanium and Zirconium Compounds - Their Application in Enamels. Ceram. Ind., vol. 24, January 1935, pp. 24-25.

An elementary account of the use of zirconium and titanium compounds in enamels. Part II of this series deals with the effect of zirconium oxide in glasses and enamels.

227. DUWEZ, P. Allotropic Transformation of Hafnium. Jour. Appl. Phys., vol. 22, No. 9, September 1951, pp. 1174-1175.

The existence of an allotropic transformation in hafnium, suggested by Zwikker in 1926, has been confirmed. The transformation temperature is 1,310° ± 10° C. The high-temperature beta-form is probably body-centered cubic.

See also abs. 119.

228. DUWEZ, P., BROWN, F. H., JR., AND ODELL, F. Zirconia-Yttria System. Jour. Electrochem. Soc., vol. 98, No. 9, September 1951, pp. 356-362.

The phase relationships in the zirconia-yttria system have been established up to 2,000° C. The addition of 0 to 5 mole-percent yttria lowers the temperature at which zirconia transforms from the tetragonal to the monoclinic form. From 7 to 55 mole-percent yttria is soluble in zirconia, and this solid solution is cubic (stabilized zirconia). A 2-phase region appears between 55 and 76 mole-percent yttria. With more than 76 mole-percent yttria, zirconia is soluble in yttria. These phase boundaries refer to the specimens rapidly cooled from 2,000° C. The effect of lowering the temperature to 1,375° C. is to increase the width of the 2 phase region between cubic zirconia and yttria solid solution. A tentative phase diagram of the zirconia-yttria system is presented. The mechanism of stabilization of zirconia by an oxide of the yttria type is discussed in relation to the crystal structure of these 2 oxides. It is concluded that scandia, as well as other oxides of the rare earth group from elements 62 to 71, should stabilize zirconia by the same mechanism. Experimental results obtained on scandia, gadolinia and samaria indicate that, as for yttria, the minimum amount of these oxides necessary to produce stabilization is about 6 mole-percent.

229. DUWEZ, P., AND ODELL, F. Phase Relationships in the Binary Systems of Nitrides and Carbides of Zirconium, Columbium, Titanium, and Vanadium. Jour. Electrochem. Soc., vol. 97, No. 10, October 1950, pp. 299-304.

Previous investigators have shown that the binary systems involving the monocarbides of zirconium, columbium, tantalum, titanium, and vanadium are of solid-solution type, except for ZrC-VC, and are almost completely insoluble in each other. The present study shows that the mononitrides of zirconium, columbium, titanium, and vanadium, which have the same NaCl-type crystal structure as the corresponding carbides, are also soluble in each other, except for the pair ZrN-VN. As for the carbides, this exception can be explained on the basis of the atomic-size rule governing the formation of solid solution. Furthermore, it is established that most of the binary systems formed by a carbide and a nitride are of the solid-solution type, provided the atomic diameters of the metal atoms do not differ by more than about 15 percent. The systems involving zirconium carbide with the nitrides were not investigated, because zirconium carbide decomposed in a nitrogen atmosphere at high temperature.

230. ___. Quantitative Analysis of Cubic and Monoclinic Zirconia by X-Ray Diffraction. Jour. Am. Ceram. Soc., vol. 32, No. 5, May 1, 1949, pp. 180-183.

The X-ray diffraction technique presents a simple method for the quantitative analysis of mixtures of polymorphic forms of the same substance. The X-ray spectrometer provides a rapid means for such work. For zirconia, the relative intensities of the cubic (111) reflection and the monoclinic (111) and $(11\bar{1})$ reflections are related to the proportions of each form present. Details of the specimen-preparation technique, instrument operation, and specific calibration curves are included.

231. DUWEZ, P., ODELL, F., AND BROWN, F. H., JR. Stabilization of Zirconia With Calcia and Magnesia. Jour. Am. Ceram. Soc., vol. 35, No. 5, May 1, 1952, pp. 107-113.

The minimum amount of calcia or magnesia required to stabilize zirconia into the cubic form is about 16 mole-percent. X-ray diffraction studies show that both calcia and magnesia are in solid solution in cubic zirconia. This solid-solution phase extends from 16 to 30 mole-percent in the case of calcia and from 16 to 25 mole-percent in the case of magnesia. These results are for specimens cooled from 2,000° C. After heating at various temperatures between 815° and 1,375° C., the calcia-stabilized zirconia remains cubic, whereas the magnesia-stabilized zirconia reverts to the monoclinic form. On the basis of the results obtained from X-ray diffraction and dilatometric measurements, information was obtained on the phase relationships in the systems zirconia-calcia and zirconia-magnesia, and some modifications to the previously published phase diagrams of these systems are proposed.

232. DYSON, G. M. Chemistry and Metallurgy of Zirconium and Hafnium. Chem. Age, vol. 15, July 3, 1926, pp. 1-3.

Discusses the occurrence, preparation, properties, and uses of the elements zirconium and hafnium.

## E

233. EASH, J. T., AND KIHLGREN, T. E. Effect of Composition on Properties and Structure of Cast Monel. Trans., Am. Foundrymen's Soc., vol. 57, 1949, pp. 535-545.

Presents a discussion of the effect of changes in the base composition, melting practice, and certain impurities on the mechanical properties and microstructure of cast Monel. The silicon content in Monel is of major importance because of its solution and precipitation hardening effects. The tensile strength ranges from 70,000 to 140,000 p.s.i. between 1.5 and 4 percent silicon. An increase in the ratio of copper to nickel increases the hardness at a given silicon level. The carbon content should not exceed the solubility limit, for the excess occurs as graphite, which decreases the strength and toughness. Sulfur will form intergranular films and low properties unless fixed by enough magnesium. Lead is detrimental to strength at normal and elevated temperatures. The effect of zirconium is demonstrated.

234. EASTWOOD, L. W., AND CRAIGHEAD, C. M. Refractories for Melting Titanium. Part I. Battelle Mem. Inst., AF-TR-6218, pt. 1, June 1950, 24 pp.

Refractory crucibles were prepared by hot pressing, compressing at room temperature, sintering at elevated temperatures, slip casting, and vapor coating. Forty-five standardized melts were prepared in the crucibles, and the resulting ingots examined for impurities. With the possible exception of zirconia, all refractories were appreciably soluble in the titanium melt. Because of the high solubility, none of these materials, with the possible exception of zirconia, appear to be appreciably better than carbon. Stabilized zirconia was the only refractory not wetted by the titanium melt. Oxygen was absorbed from the $ZrO_2$ to produce very high hardnesses but the zirconium content of the ingots generally was low, possibly indicating that $ZrO_2$ was partially reduced and that lower oxides of zirconium might be useful.

ECONOMOS, G. See abs. 443, 600.

EDWARDS, J. E. See abs. 627.

EDWARDS, J. W. See abs. 742.

235. EDWARDS, R. K., LEVESQUE, P., AND CUBICCIOTTI, D. Chemical Thermodynamics of Materials at High Temperatures. Solid Solution Equilibria in the Zirconium-Hydrogen System. Illinois Inst. Tech., Tech. Rept. 13, August 1953, 14 pp.

The solubility of hydrogen in zirconium has been determined as a function of temperature and hydrogen pressure in the temperature range 600° to 900° C. The solubilities obtained for a hydrogen pressure of one atmosphere are about 10 percent higher than those obtained by Hall, Martin, and Rees. A partial binary-phase diagram is presented and correlated insofar as possible with previous X-ray work. There appears to be a new phase (delta) in the composition range 59.4 to about 61 atom-percent hydrogen. The zirconium-rich boundary of this phase is invariant with temperature. This phase is apparently separated from the epsilon phase (which includes the composition $ZrH_2$) by a very narrow 2-phase field, which has generally escaped detection and was only indirectly established in this experimentation.

236. ___. Chemical Thermodynamics of Materials at High Temperatures. Solid Solution Equilibria in the Ternary System Zirconium-Oxygen-Hydrogen. Illinois Inst. Technol., Tech. Rept. 14, August 1953, 15 pp.

The solubility of hydrogen in the solid solution of the ternary system zirconium-oxygen-hydrogen has been determined as a function of temperature, composition, and equilibrium hydrogen pressure. The data have been correlated with those of the related binary systems and some previous work in the ternary system, and the solid-state chemistry has been represented by an extensive provisional partial ternary-phase diagram. A new single-phase region (delta) lying between the alpha zirconium and epsilon (approximately $ZrH_2$) phases has been established as belonging both in the binary and ternary systems. The hydrogen saturation boundary of the alpha phase shows that, initially, hydrogen may be replaced by oxygen on a 3-to-1 basis in the alpha phase. The hydrogen saturation boundary of the delta phase indicates that hydrogen may be replaced by oxygen on a 3.5-to-1 basis in the delta phase.

237. **ELECTRONICS.** Zirconium Arc Lamp. Vol. 23, No. 2, February 1950, pp. 184, 186, 188.

Describes a high-intensity electric arc light, one-eighth as bright as the sun. The light source, which operates in the open air and not in a glass bulb, is a pool of molten zirconium metal, which is maintained at a temperature near 6,500° F.

ELLSWORTH, H. V. See abs. 609.

ELVING, P. J. See abs. 606.

238. **EMELÉUS, H. J., AND WOOLF, A. A.** Reaction of Bromine Trifluoride With Oxides and Some Oxy-Acid Salts. Jour. Chem. Soc., pt. 1, 1950, pp. 164-168.

The reaction of bromine trifluoride with 28 oxides, including $ZrO_2$, was studied. With CuO, $B_2O_3$, $Tl_2O_3$, $SiO_2$, $GeO_2$, $TiO_2$, $As_2O_3$, $Sb_2O_3$, $SeO_2$, $UO_3$, and $I_2O_5$, oxygen evolution was quantitative; in other instances, a mixture of oxide and fluoride resulted. Metaphosphates were converted quantitatively into hexafluorophosphates, but orthophosphates gave a mixture of fluorophosphate and bromofluoride. An ionic reaction mechanism involving the "acid" $BrF_2^+PF_6^-$ is postulated to explain the formation of hexafluorophosphate. Orthoarsenates resembled orphophosphates. Potassium persulfate and pyrosulfate gave fluorosulfonate, whereas the pyrosulfite, thiosulfate and sulfate gave equimolecular mixtures of fluorosulfonate and bromofluoride. Sodium dithionite and sulfite gave only bromofluoride. The relationship between the products and the anion structure is discussed. Oxygen was liberated quantitatively from iodates and bromates but incompletely from chlorates and carbonates.

239. **EMLEY, E. F.** Refining of Magnesium. Inst. Min. and Met., 1950, pp. 407-443.

Discusses the special refining problems encountered in the commercial development of zirconium alloys.

ENGELKEMEIR, D. W. See abs. 102.

240. **ENKVIST, T., AND MÄKELÄ, K.** Lubricating Oil From Pine Tar and Tall Oil. Effect of Catalysts on the De-Carboxylation of Resin Acids From Tall Oil and Tall-Oil Pitch. Finska Kemistsamfundets Medd., vol. 57, 1948, pp. 21-61.

Describes investigations in connection with research undertaken to develop methods of manufacturing lubricating oil from pine tar and tall oil utilizing dedecarboxylation catalysts. Cerium and zirconium dioxide catalyze the decarboxylation of resin acids from tall oil. Results for $ZrO_2$ catalysts employed are given in table form.

241. **ESPE, W.** New Getter Materials for the High-Vacuum Technique. Pwdr. Met. Bull., vol. 3, No. 5, 1948, pp. 100-111.

The use of getter materials in the high-vacuum technique is based upon the ability of certain metals to eliminate free gases by adsorption, absorption, or occlusion. This effect is widely utilized to reduce the pumping period and to improve and maintain a high vacuum or the purity of an atmosphere of noble gases. Zirconium powder has been used successfully for coating nickel, iron, or carbon electrodes. Methods of utilizing zirconium are mentioned.

242. **ESPE, W., KNOLL, M., AND WILDER, M. P.** Getter Materials for Electron Tubes. Electronics, vol. 23, October 1950, pp. 80-86.

Discusses the specific action and applicability of tantalum, columbium, zirconium, thorium, titanium, aluminum, magnesium, barium, and phosphorus as getters for vacuum tubes. These metals can be formed as wires, sheets, tubes, and tablets or serve as powder coatings on hot electrodes.

243. ESPERSEN, G. A. Zirconium for Electron Tubes. Foote Prints, vol. 18, No. 1, 1946, pp. 3-7.

Discusses some of the uses of zirconium in electronic tubes. Uses of this metal, welding flux, grid-emission inhibitor, getter in vacuum tubes, vacuum accelerator, and getter for metal evaporation, are described relative to a number of types of tubes.

F

FAIRBAIRN, H. W. See abs. 380.

244. FAIRHALL, L. T. Inorganic Industrial Hazards. Physiol. Rev., vol. 25, 1945, pp. 182-202.

Reviews health hazards of a number of metals including zirconium. It has been noted that zirconium has only a mild pharmacological action and may lack physiological effect in small amounts. In the form of the soluble tartrate complex, the intravenous introduction of this salt in relatively large doses in rabbits causes death. The zirconium compounds in technical use are very insoluble, however, and no cases of systemic poisoning have been reported.

FANO, L. See abs. 807.

245. FASSEL, V. A., AND ANDERSON, C.H. Quantitative Spectrographic Analysis of Zirconium-Hafnium Mixtures. Ames Lab., Iowa State Coll., AECU-919, Nov. 10, 1950, 15 pp.

Describes a spectrographic method for the analysis of zirconium-hafnium mixtures covering the hafnium-zirconium concentration ratio range from 0.001 to 100. The samples are excited as conducting pellets prepared from mixtures of the combined oxides with powdered flake graphite. An over-damped condenser discharge is used for excitation. By utilizing a series of internal-standard line pairs, the complete concentration range can be covered by a single exposure. At the same time, photographic photometry errors can be reduced by restricting the intensity-ratio range over which these line pairs are measured. The unique similarity in the physical and chemical properties of zirconium and hafnium combined with the use of line pairs of similar excitation characteristics provides a system in which almost ideal internal-standard compensation can be achieved. Experimental results indicate that large variations in excitation conditions, the presence of up to 5 percent extraneous elements, variations in graphite:oxide ratios in the pellet, change in crystal structure of the oxides, and change in the chemical form of the samples apparently have no effect on the analytical results. Precision determinations showed a standard deviation of about 1.5 to 2.0 percent.

246. FASSEL, V. A., HOWARD, A. M., AND ANDERSON, D. Conducting Briquet Technique of Spectrographic Analysis. Anal. Chem., vol. 25, No. 5, May 1953, pp. 760-763.

Zirconium is a typical member of a group of new and industrially important metals that cannot be conveniently employed as metal self-electrodes for spectrographic analysis. Although zirconium metal can be readily converted to the oxide and excited in a conventional direct-current carbon arc, experimental results have shown that the highly refractory oxide cannot be vaporized and excited in a reproducible manner. Moreover, acceptable internal standardization cannot be achieved with zirconium lines because of the selective volatilization mechanism. The application of the conducting briquet excitation technique was investigated. Unidirectional, interrupted, high-energy, arc-like discharges achieved uniform and reproducible volatilization of the zirconium oxide particles blended into the conducting powdered graphite matrix. Negligible selective volatilization was observed. Details are presented for the determination of aluminum, calcium, chromium, copper, iron, nickel, magnesium, silicon, and titanium in zirconium oxide with a coefficient of variation ranging from 3.1 to 6.9 percent for the various impurities. Because this technique makes it possible to excite refractory samples with controlled excitation sources, it should find increasing application in spectrographic methods for the analysis of nonconducting substances.

247. FAST, J. D. Working of Ductile Zirconium and Titanium. Metall., vol. 17, 1938, pp. 459-462.

This report covers in detail the solubility of nitrogen and oxygen in solid titanium and zirconium; effect of these gases on mechanical properties; production of the pure ductile metal; forging, drawing and rolling; manufacture of hollowware from zirconium; mechanical and electrical properties, and loss of mechanical strength.

248. ___. Zirconium as a Getter. Foote Prints, vol. 13, No. 1, June 1940, pp. 22-30; Met. Eng. Digest (In Metals and Alloys); vol. 12, 1940, p. 348.

Zirconium possesses the additional property of continuing to bind gases in the vapor or solid state after the tube has been sealed off. No impervious oxide films are formed on this metal at high temperatures, and the solubility of $O_2$ and $N_2$ in zirconium is very high; good protective films are formed at low temperatures so that the metal is stable in air. Also the solubility of $H_2$ in zirconium is high. (Chem. Abs.)

See also abs. 182, 183.

249. FAUST, E. H., JR., AND TINKELPAUGH, J. High-Temperature Laboratory Kiln. Report No. 20. New York State Coll. Ceram., NP-665, June 23, 1948, 14 pp.

Describes the design and firing behavior of a gas-fired, stabilized, zirconia-lined, high-temperature laboratory kiln.

FEHRER, H. See abs. 780.

250. FEILD, A. L. Effect of Zirconium on Hot-Rolling Properties of High-Sulfur Steels and the Occurrence of Zirconium Sulfide. Trans. AIME No. 1306, 1924, pp. 201-217.

Describes the hot-rolling properties of a number of high-sulfur ingots, with and without a zirconium content, as well as the appearance and condition of the plate rolled therefrom.

251. ___. Some Effects of Zirconium in Steel. Trans. AIME No. 1266-S, 1923, pp. 848-894.

This paper contains an account of experimental results obtained in an extensive investigation of steels containing zirconium. In addition to the methods of manufacture and tests employed in the work, there is described experimental evidence on which are based certain definite conclusions regarding the remarkable effects brought about by the presence in steel of relatively small percentages of zirconium.

252. FELDMAN, C. Direct Spectrochemical Analysis of Solutions Using Spark Excitation and the Porous Cup Electrode. Oak Ridge Nat. Lab., AECD-2392, Feb. 1, 1948, 10 pp.

The porous-cup electrode consists of a 1/4- by 1-1/2-inch right cylindrical graphite rod, with a 1/8-inch hole drilled along its axis from one end to within approximately 1.3 mm. of the other end. It is used as the upper electrode, with the open end up. In operation a long-nosed pipette, containing 0.2 to 0.3 ml. of the solution to be analyzed, is inserted into the cavity in the upper electrode until its tip touches bottom; the solution is then expelled as the pipette is withdrawn. The lower electrode is a solid 1/8-inch graphite rod. A synchronous spark from a Baird high-voltage spark source or a 220-volt intermittent a.c.-d.c. arc is first applied for 5 to 10 seconds, using a 2-mm. analytical gap. The heat thus produced helps the liquid to soak through the bottom of the porous cup and reach the sparking surface. After a short (~15-second) rest, the sparking is resumed and the exposure begun. The liquid feeds through by wick action, constantly renewing the thin surface film of liquid as it is dispersed by the spark. Spattering does not occur, as the spark never strikes the body of the liquid. Almost all the energy of the spark is dissipated in vaporizing and exciting the liquid film, so that the sample does not boil over. A sample of the size mentioned lasts as long as 240 seconds. Successful analyses have been made of acidic, neutral, and slightly alkaline solutions having a wide range of salt concentrations. The technique is also applicable to some solutions in organic solvents. The following approximate sensitivity limits have been attained: 0.01-0.1 p.p.m. beryllium, magnesium; 0.1-1.0 p.p.m. silver, aluminum, lithium; 1.0-10 p.p.m. boron, bismith, columbium, cobalt, chromium, copper, iron, gallium, germanium, hafnium, indium, lanthanum, manganese, nickel, lead, rhenium, titanium, vanadium, zirconium; 10-100 p.p.m. arsenic, gold, columbium, cerium, cesium, mercury, phosphorus, platinum, ruthenium, antimony, tin, thorium, zinc; and 100-1,000 p.p.m. tellurium, tungsten.

253. FELDMAN, C. Spectrochemical Determination of Hafnium-Zirconium Ratios. Anal. Chem., vol. 21, No. 10, October 1949, pp. 1211-1215.

A spectrochemical technique is presented for determining hafnium:zirconium ratios in the range of 100 hafnium/zirconium = 0.073 to 9.28 by weight, with and without the aid of hafnium-free zirconium preparations. The sample is brought into solution in 10 percent sulfuric acid and sparked by the porous-cup technique. The intensity ratio hafnium II 2,641.406/zirconium 2,761.911 is measured, and the hafnium-zirconium ratio is read from a standard curve.

FELLOWS, D. M. See abs. 601.

254. FERGUSON, J. D. Zirconium Content in Ores and Alloys. Eng. Min. Jour., vol. 106, No. 18, Nov. 2, 1918, pp. 793-794.

Methods are given in detail for the determination of zirconium in ores and steel.

**FERNELIUS, W. C. See abs. 749.**

**FINDLAY, G. R. See abs. 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209.**

**___. Preparation of Ductile Zirconium Summary of Thermodynamic Data. See abs. 202.**

**255. FINLAY, W. L., AND JAFFEE, R. I. Titanium and Zirconium. (Ch. in AIME,** Modern Uses of Nonferrous Metals.) 1953, pp. 432-439.

**A general survey of the zirconium field. Included are discussions of the properties, technology, extraction, and applications of zirconium. The iodide and Kroll processes are compared.**

**FINNEY, B. C. See abs. 3.**

**256. FISHEL, W. P., AND HAYES, J. C. Distribution of Carbon Between the Zirconium and Ferrite Phases. Proc. Indian Acad. Sic., vol. 58, 1949, pp. 132-136.**

**All the carbon in a steel whose atomic ratio zirconium:carbon is greater than 1 will be united with the zirconium. If the ratio zirconium:carbon is less than 1, a fairly direct ratio is between this and percent of total carbon as zirconium:carbon. $Fe_3C$ appears only if zirconium:carbon is less than 1. Zirconium does not enter $Ar_1$ transformation because ZrC separates in the crystalline or crowfoot structure at a temperature well above the $Ar_1$; therefore, zirconium does not increase the carbon content of the eutectoid. However, in order to have a matrix of pearlite, the steel must contain more than 0.85 percent carbon. The excess carbon unites with zirconium and is in no way connected with the eutectoid separation. Particles of ZrC in steels function as inclusions only.**

**257. FISHER, T. F., AND WEBER, C. E. Cathodic Sputtering for Micro-Diffusion Studies. Knolls Atomic Power Lab., AECU-1712, 1952, 14 pp.**

A method based on sputtering of metal from the cathode of a gas glow-discharge tube has been developed to allow uniform removal of microlayers of metal from cylindrical specimens. This technique is directly applicable to diffusion studies and offers many advantages over other more common methods.

FITZSIMMONS, E. S. See abs. 585, 824.

258. **FITZWILLIAM, J., KAUFMAN, A., AND SQUIRE, C.** Magnetic and X-Ray Studies on Titanium and Zirconium With Dissolved Hydrogen. Jour. Chem. Phys., vol. 9, September 1941, pp. 678-682.

Dissolved hydrogen in titanium and zirconium has the effect of changing the lattice of these metals from close-packed hexagonal to a nearly cubic-face-centered lattice. The paramagnetic susceptibility of the system titanium-hydrogen and also zirconium-hydrogen has a value at room temperature different from that of the respective pure metals. The dependence of susceptibility on the hydrogen concentration has been investigated for zirconium. A small trace of iron impurity, which was dissolved in the zirconium, was found to precipitate out and regain its ferromagnetic property when the zirconium was allowed to soak up hydrogen.

259. **FLAGG, J. F., LIEBHAFSKY, H. A., AND WINSLOW, E. H.** Spectrophotometric Study of Three Zirconium Lakes. Jour. Am. Chem. Soc., vol. 71, November 1949, pp. 3630-3632.

Spectrophotometric evidence indicates that the lakes formed by zirconium with each of the dyes, alizarin, purpurin, and quinalizarin, is a definite compound, the two constituents being combined in equimolar amounts. The spectrophotometric behavior and the incomplete lake formation observed under some conditions resemble closely experimental results obtained on the hafnium-alizarin lake. On this basis, it is logical to assign to the three lakes studied here a chelate-ring formula analogous to that given the lake formed by hafnium and alizarin.

260. **FLASER, F. W., MOSKOWITZ, D., AND POST, B.** Study of Some Binary Hafnium Compounds. Jour. Metals, vol. 5, No. 9, September 1953, pp. 1119-1120.

Lattice parameters of various hafnium compounds, two borides, a carbide, and a nitride were determined. Some physical properties were measured, and comparisons with the properties of the corresponding zirconium compounds were drawn.

261. **FLEISCHER, M.** Hafnium Content and Hafnium-Zirconium Ratio in Minerals and Rocks. Geol. Survey Bull. 1021-A, 1955, 13 pp.

Compilation of all published data on the hafnium content and hafnium:zirconium ratio in minerals and rocks. The hafnium:zirconium ratio is probably about 0.02 in the earth's crust. Minerals from alkalic rocks, such as nepheline syenites, have lower hafnium:zirconium ratios than does zircon from granitic rocks. Minerals from granitic pegmatites have the highest hafnium:zirconium ratios, especially some peculiar varieties of zircon such as alvite, cyrtolite, and maegite, and the rare scandium silicate, thortveitite, which is the only mineral that is reported to contain more hafnium than zirconium.

262. **FORSLING, W.** Purification of Zirconium From Hafnium by Anion Exchange in Hydrochloric and Hydrofluoric Acid Mixtures. Arkiv för Kemi, vol. 5, No. 46, 1953, pp. 503-516.

A radiochemical investigation has been made of suitable conditions for separation of zirconium from hafnium by anion exchange in hydrochloric and hydrofluoric acid mixtures. The main object of this work was to study the possibility of purifying zirconium from such amounts of hafnium, as generally occur together with zirconium in nature.

A relatively high weight of zirconium per unit of weight of anion exchanger was used. It was intended that the process should be useful in practice and for this reason very low acid concentrations were to be preferred. Ninety-eight percent of a zirconium amount of about 100 mg. per $cm^2$ of cross-sectional column area could be obtained completely free from hafnium in a single column operation. The anion exchanger used was Amberlite IRA-400.

263. FORSYTHE, W. E. Radiation From Oxides. I. Emissive Power of Zirconium Oxide. Am. Phys. Soc., vol. 20, No. 1, Apr. 5, 1922, pp. 101-102.

The emissive power of zirconium oxide for red radiation $(\lambda = .665\mu)$ has been measured by two methods. The first consisted of heating on a platinum strip a small piece of the oxide, which had been baked at a temperature of about 1,800° K. and measuring the relative brightness of the oxide and the platinum strip. The second method consisted in pressing the oxide in the form of hollow glowers and then making a small radial hole, from which the true temperature could be determined.

FOSTER, E. L., JR. See abs. 684.

264. FOSTER, W. R. Useful Aspects of the Fluorescence of Accessory-Mineral-Zircon. Am. Mineral, vol. 33, No. 11-12, November-December 1948, pp. 724-734.

The mineral zircon has long been known to exhibit fluorescence when exposed to ultraviolet radiation. Little practical use appears to have been made of this phenomenon. In this report its application is recommended in the inspection of commercial concentrates of zircon and of other minerals containing zircon as an impurity. Comparison of the fluorescent behavior of grains of zircon from igneous rocks of different ages and from igneous, as compared with sedimentary, sources reveals certain contrasts. The possible usefulness of such contrasts in the solution of a number of petrological problems is discussed. Reference is also made to the fluorescence of accessory-mineral apatite and of certain other minerals found in association with zircon.

265. FOUNDRY. Zirconium is Deoxidizer in Cast Iron. Vol. 48, Nov. 1, 1920, pp. 878-879.

Zirconium has been added to the list of deoxidizers useful for the purification of cast iron. This report is a summary of experimentation and results, which culminated in the successful use of zirconium as a deoxidizer.

266. FOWLES, G. W. A., AND POLLARD, F. H. Studies on the Behavior of Halides of the Transition Metals With Ammonia. Part III. The Reaction of Zirconium and Thorium Tetrachlorides With Ammonia. Jour. Chem. Soc., vol. 12, December 1953, pp. 4128-4132.

The reaction of zirconium and thorium tetrachlorides with ammonia has been studies tensimetrically at -36° and -44°. Whereas zirconium tetrachloride gives an amidochloride, $ZrNH_2Cl_3$, thorium tetrachloride forms only an addition complex, which dissociates into its constituents in vacuo at 200°. The mechanism of the reaction of ammonia with the Group IV A tetrachlorides is discussed and compared with the mechanisms proposed in recent analogous "alcoholysis" studies.

267. FOX, F. A. Notes on Magnesium Alloys. Engineer, vol. 191, Feb. 2, 1951, pp. 148-150.

Surveys the manufacture, properties, and uses of magnesium-base alloys; discusses effects of the alloying elements, zirconium, aluminum, magnesium, cerium, on the physical and mechanical properties of the alloys; and tabulates the tensile properties of the common Elektron alloys.

FOX, J. D. See abs. 42.

268. FRANKLIN INSTITUTE. Second Annual Report of the Work of the Bartol Research Foundation of the Franklin Institute. NP-4300, Sept. 30, 1952, 152 pp.

Measurements were made of the energies of the gamma rays emitted by the (65 ± 2)-day $Zr^{95}$ and its (35 ± 1)-day $Nb^{95}$ daughter element. Energies of 0.73, 0.23, and 0.92 Mev. were found for the parent and 0.75, 0.758, and 0.77 Mev. for the single gamma ray of the daughter. Approximately 2 percent of the beta-ray disintegrations of $Zr^{95}$ terminate at a 90-hour metastable level of the residual nucleus, radioactive $Nb^{95}$. The energy of the isomeric transition was found to be 0.216 and 0.24 Mev. The radiation is totally converted. The gamma ray, which appeared to have an energy of 0.92 Mev. was found in both the zirconium and niobium fractions. However, the beta-gamma coincidence rate of $Zr^{95}$ indicates that each beta of $Zr^{95}$, if followed by less than 0.3 Mev. of gamma-ray energy and the beta-gamma coincidence rate of carefully purified $Nb^{95}$, is great enough to explain the hard gamma ray thought to be of energy 0.92 Mev. Consequently, the presence of this ray in the zirconium fraction is attributed to incomplete chemical separation of the daughter element. Because of conflicting reports concerning gamma radiations, the properties of $Zr^{95}$-$Nb^{95}$ have been investigated.

269. FRECHETTE, V. D. Fundamentals of Metal-Ceramic Mixtures at High Temperatures. Progress During Period Feb. 1 to Mar. 31, 1950 (Periodic Status Rept. 19), Alfred Univ., NP-1467, Mar. 31, 1950, 13 pp.

The results of investigations of the systems of metal-ceramic mixtures are given, including beryllium, zirconium, aluminum with $Al_2O_3$, BeO, and $ZrO_2$, with special emphasis placed on forming dense specimens. Other studies include oxidation kinetics, reaction products formed, techniques in forming dense specimens, and thermal diffusivity of some of the metal-ceramic mixtures considered. A radioactive-tracer technique is given for determination of the diffusion rate from an oxidizing metal into a polycrystal compact (TID-3010).

270. CRANDALL, W. B., AND LAWRENCE, W. G. Fundamental Properties of Metal-Ceramic Mixtures at High Temperatures. Progress During Period Aug. 1 to Sept. 30, 1950. (Periodic Status Rept. 22.) Alfred Univ. NP-1779, Sept. 30, 1950, 16 pp.

Methods were developed for preparing pure intermetallics for the purpose of accumulating fundamental data pertaining to them. Pure intermetallics and intermetallic-ceramic mixtures were formed by several methods for pure intermetallics, hot pressing, neutral-atmosphere firing, flash firing and spot-welding; for intermetallic-ceramic systems, thermite reaction, addition, and partial oxidation. Oxidation resistance at 1,400° C. was determined on selected specimens. Various zirconium samples reformed by cold pressing include $53ZrH_2$-47Si with an oxidation resistance of 9, 50Al-$25ZrO_2$-$25O_2$ with a resistance of 10, and 50Al-$40ZrO_2$-10MgO with a resistance of 9. X-ray diffraction analyses were made on each of the specimens and checked.

271. ___. Fundamental Properties of Metal-Ceramic Mixtures at High Temperatures. Progress During Period Feb. 1 to Mar. 31, 1951 (Periodic Status Rept. 25). Alfred Univ., NP-3044, Mar. 31, 1951, 8 pp.

Oxidation-resistance studies have been completed on 3 component systems consisting of 40 percent oxide ($Al_2O_3$ or MgO), 40 percent metalloid (SiN, TiN, SiC, Zrc, $ZrB_2$, $CrB_2$, or $TiB_2$), and 20 percent intermetallic (chromium-aluminum, molybdenum-aluminum, or nickel-aluminum). Those mixtures containing SiN and SiC were found to have the best oxidation resistance. Further work on thermal-shock-resistance theory has indicated that the nature of failure obtained on heating is much more complex than that during cooling. Consequently, it is the heating cycle that offers the greatest possibilities experimentally to prove or disprove the overall theory. Thermal-expansion measurements were made on the high-temperature stable systems MgO (single crystal), $ZrB_2$, and others (TID-3010).

272. CRANDALL, W. B. Fundamental Properties of Metal-Ceramic Mixtures at High Temperatures. Progress During Period Apr. 1 to May 31, 1951 (Periodic Status Rept. No. 26). Alfred Univ. NP-3115, May 31, 1951, 15 pp.

X-ray diffraction studies were run to determine the products existing after firing ZrC and $ZrB_2$ with mixtures of various metallic oxides and intermetallic compounds; $ZrO_2$ was identified in most cases (TID-3010).

273. FRIEND, J. A. N., COLLEY, A. T. W., AND HAYES, R. S. Vapor Density of Zirconium Tetrachloride. Jour. Chem. Soc., 1930, pp. 494-497.

Results show no evidence of association at 400° or above. The 4 high results at 500° and the 1 at 700° are believed to be due to decomposition as indicated below. The vapor density of zirconium tetrachloride in chlorine falls with the rise of temperature and appears to fall slightly with dilution. Presumably the vapor first dissociates into the trichloride and free chlorine, $2ZrCl_4 \rightleftarrows 2ZrCl_3 + Cl_2$. The decomposition can hardly end there, however, since, according to Ruff and Wallstein, the trichloride also dissociates above 330°; thus, $2ZrCl_3 \rightleftarrows ZrCl_4 + ZrCl_2$. Moreover, above 600° the dichloride deposits zirconium, $2ZrCl_2 = ZrCl_4 + Zr$. The reactions in the vaporizing tube may thus be very complex, and complete equilibrium could not be obtained in the brief course of experimentation.

274. FRITZ, J. S., AND FULDA, M. O. Titrimetric Determination of Zirconium. Ames Lab., Iowa State Coll., ISC-382, July 28, 1953, 12 pp.

Describes a quick, direct titrimetric method for zirconium. The titration is carried out in acid solution with Versene (disodium dihydrogen ethylenediaminetetraacetate), a stable, soluble complex being formed. A visual indicator gives a sharp end point. Iron, thorium, molybdenum, and bismuth constitute important interferences, but most other metals do not affect the results. Tin and titanium reduce the sharpness of the end point but do not otherwise interfere.

FROST, P. D. See abs. 584.

275. FUJIWARA, S. Absorption of Nitrogen by Zirconium and Iron. Bull. Chem. Soc. (Japan), vol. 23, No. 1, 1950, pp. 20-22.

The weight increase of zirconium and iron powders, due to absorption of $N_2$ at increasing temperatures, starts at 265 and 650°, respectively, comes to a first equilibrium at 600 and 730°, and to a second at 900 to 950 and 945°, respectively; zirconium-iron powders containing 28.1 and 29.9 percent zirconium exhibit starting and equilibrium temperatures similar to those of pure iron powders (TID-3010).

FULDA, M. O. See abs. 274.

## G

276. GANGLER, J. J. Some Physical Properties of Eight Refractory Oxides and Carbides. Jour. Am. Ceram. Soc., vol. 33, No. 12, December 1950, pp. 367-375.

An investigation of eight hot-pressed refractory oxides and carbides for possible gas-turbine application was undertaken. The properties, short-time tensile strength at elevated temperatures, thermal-shock resistance, coefficient of linear expansion, and density were determined. The compositions of the ceramics included beryllium oxide, magnesium oxide, stabilized zirconia, zircon, boron carbide, 85 percent silicon carbide plus 15 percent boron carbide, titanium carbide, and zirconium carbide. The short-time tensile strengths of these ceramics were determined at 1,800° and 2,200° F. Resistance to thermal shock was determined by rapid cooling in air to room temperature from 1,800°, 2,000°, 2,200°, and 2,400° F. The thermal-expansion characteristics of these materials were studied from room temperature to 1,100° F. Zirconium carbide was the strongest material at 2,200° F., with a maximum short-time tensile strength of 15,850 p.s.i.; however, it exhibited extremely poor resistance to oxidation.

277. **GARRISON, W. M., HAYMOND, H. R., AND MAXWELL, R. D.** Rapid Electrical Method of Separating Carrier-Free Radioactivities. Radiation Lab., Univ. California, AECU-228, UCRL-318, Mar. 15, 1949, 2 pp.

A method is given for separation of radio-zirconium from radioyttrium and rare-earth activities. A sample of solution was electrolyzed in a stack saturated with 1M ammonium oxalate. Columbium (niobium) and zirconium were recovered in the anode papers. Yttrium and rare-earth activities (europium, neodymium, and praseodymium) remained on the original paper. A second sample was electrolyzed in 3N hydrochloric acid. Columbium and zirconium did not migrate; yttrium and the rare earths were recovered in cathode papers.

278. **GEACH, G. A., AND SUMMERS-SMITH, D.** Laboratory Arc-Furnace for Melting Alloys Containing the Refractory Transition Metals. Metallurgia, vol. 42, No. 250, August 1950, pp. 153-156.

In the furnace described the specimen, resting upon a water-cooled copper hearth, is the positive pole of a heavy-current d.c. arc. The material melts, all except a thin layer near the hearth. This protects it from copper contamination. This layer is itself melted later after turning the specimen over. An inert atmosphere of purified argon protects the charge. Fifty grams of tungsten can be melted in such a furnace in a few minutes; alloys of uranium or titanium are obtained untarnished and virtually uncontaminated, and malleable zirconium remains perfectly malleable after melting. It is quite simple to prepare, in 1 day, 10 or 15 melts of what have hitherto been the most difficult of alloys to obtain. A detailed description of the furnace is given (TID-3010).

**GEE, E. A.** *See* abs. 800.

279. **GEIGER, J. S., HOGG, B. G., DUCKWORTH, H. E., AND DEWDNEY, J. W.** $Zr^{92}$-$Mo^{92}$ and $Zr^{94}$-$Mo^{94}$ Pairs and the $Zr^{96}$-$Mo^{96}$-$Ru^{96}$ Triplet. Phys. Rev., vol. 89, No. 3, Feb. 1, 1953, pp. 621-623.

Mass spectrographic measurements are reported of the following mass differences: $1/2W^{184}$-$Zr^{92}$, $1/2W^{184}$-$Mo^{92}$, 1/2 $Os^{188}$-$Zr^{94}$, 1/2 $Os^{188}$-$Mo^{94}$, 1/2 $Os^{192}$-$Zr^{96}$, 1/2 $Os^{192}$-$Mo^{96}$, and 1/2 $Os^{192}$-$Ru^{96}$. These results are used to check and supplement existing transmutation and disintegration data in the region of the $Zr^{92}$ - $Mo^{92}$ and $Zr^{94}$ - $Mo^{94}$ isobaric pairs and the $Zr^{96}$ - $Mo^{96}$- $Ru^{96}$ isobaric triplet.

**GEISLER, A. H.** *See* abs. 422.

280. **GEORGE, D.** Mineralogy of Uranium and Thorium Bearing Minerals. Raw Materials Operations Office, RMO-563, January 1949 (rev.), 198 pp.

This report is concerned with the mineralogy and occurrence of uranium-bearing minerals, including zircon and zirkelite. Section I is devoted to distribution, chemistry, occurrence, and classification of the minerals; and Section II describes the individual minerals.

281. **GERMAN, W. L.** Zircon and Zirconia. Ceramics, vol. 5, No. 60, February 1954, pp. 540-544.

This article summarizes the uses of zircon and zirconia to industry.

___. *See* abs. 116, 117.

282. **GHOSH, S., AND DHAR, N. R.** Relation Between Hydration and Stability of Sols and the Bivalent Nature of Fluoride Ion. Jour. Indian Chem. Soc., vol. 5, 1928, pp. 303-311.

Zirconium hydroxides, prepared in the hot and cold conditions, have virtually the same viscosity and form stiff jelly in both instances. Viscosities of zirconium hydroxide, vanadium pentoxide, and ceric hydroxide are greater than those of ferric, chromium, and aluminum hydroxides. Jellies are formed more readily with the first group of hydroxides than with the second. Tendency to form a jelly and high viscosity are associated with a higher degree of solvation of the sol and are the most important criteria of lyophile colloids. Fluoride ions exist in the bivalent condition ($F_2''$) in aqueous solution and exert a coagulating effect of the same order as the bivalent ions, sulfate, oxalate, and tartrate.

283. **GIBBS, R. C., AND WHITE, H. E.** Relations Between Doublets of Stripped Atoms in Five Periods of the Periodic Table. Phys. Rev., vol. 33, February 1929, pp. 157-162.

Principal and diffuse doublets of stripped atoms in five periods of the periodic table from lithium I to oxygen VI, sodium I to chlorine VII, potassium I to manganese VII, rubidium I to zirconium IV, and cesium I to praseodymium V. Combining the data now available for the 1-electron systems of the 2d, 3d, 4th, 5th and 6th periods, certain regularities are found to exist between the successive elements in each period and between corresponding elements in successive periods. These regularities are found by applying the regular and irregular doublet laws. For the long periods that involve more penetrating orbits, extrapolations of $Z_i$ and $s_i$ (Landé's formula) prove to be better guides in identifying doublets of the higher members of a sequence, although extrapolation of s (Sommerfeld's formula) is entirely satisfactory for the sequences in the short periods. Using the former, a correction was made on previous identifications of the principal doublet of cerium IV. The tighter binding of the d electron over both the s and p electrons starting with scandium III, yttrium III, and lanthanum III in the three long periods is especially well brought out by the Moseley type of diagram. Evidence is presented to indicate that the unexcited state of cerium IV involves a 5d rather than a 4f electron. New data are given for vanadium V, chromium VI and lanthanum III.

284. **GIBSON, G. E., AND BROWN, H.** Relation Between Atomic Number and Isotopic Number for Stable Isotopes. Phys. Rev., vol. 53, 1938, p. 846.

A brief note on the nonradioactive isotopes of $_{40}Zr^{88}$.

GILBERT H. L. See abs. 463.

285. **GILBERT, H. L., MORRISON, C. Q., JONES, A., AND HENDERSON, A. W.** Caustic Soda Fusion of Zirconium Ores. Bureau of Mines Rept. of Investigations 5091, 1954, 31 pp.

Zircon sand may be reacted with sodium hydroxide at 600° C. to form sodium zirconate and sodium silicate. Sodium zirconate is water insoluble and so may be washed free of sodium silicate. The sodium zirconate may then be converted to zirconyl chloride by the action of hydrochloric acid and the zirconyl chloride crystals separated by cooling the solution. This approach produces zirconyl chloride of satisfactory purity with less cost than is involved in buying anhydrous zirconium chloride and converting it. A proposed design for a plant is given.

GILES, L. V. See abs. 791.

286. **GILLETT, H. W., AND MACK, E. L.** Experimental Production of Alloy Steels. Bureau of Mines Bull. 199, 1922, 81 pp.

Describes an experimental indirect-arc furnace for the production of zirconium series of alloy steels. The addition to steel of such alloying elements as tungsten, uranium, vanadium, chromium, molybdenum, nickel, silicon, manganese, zirconium, titanium, aluminum, cerium, boron, and copper has been studied quantitatively with special reference to alloy recovery. With zirconium, the lowest recoveries were obtained when ferroalloys made by reduction of zirconium ore with carbon were used; often the recovery was practically zero. With ferrozirconium alloys, made by reduction of zirconium ore by the Thermit reaction alone, without electrical heating, the recovery of zirconium was low - never over 23 percent and averaging about 10 percent. Nickel-zirconium alloys gave a better recovery of zirconium; an average recovery of 40 to 50 percent being obtained when the alloy was added to the furnace at the end of the heat. The best zirconium recoveries were obtained with alloys containing about 30 percent zirconium and 45 percent silicon, and 27 percent zirconium, 35 percent silicon, and 22 percent nickel.

287. GILMAN, H., AND JONES, R. G. Organometallic Compounds of Titanium, Zirconium and Lanthanum. Jour. Organic Chem., vol. 10, 1945, pp. 505-515.

This report discusses the preparation of organometallic compounds of titanium, zirconium, and lanthanum and the reaction mechanisms on the intermediate formation of these types.

GITMAN, E. B. See abs. 624.

288. GLASER, F. W. "Borolite" Zirconium Boride 101, Physical Properties. Jour. Metals, vol. 6, No. 11, November 1954, p. 1228.

Physical properties of zirconium boride are discussed briefly and given in table form.

See also abs. 629, 714.

289. GLASER, F. W., AND POST, B. System Zirconium-Boron. Jour. Metals, vol. 5, No. 9, September 1953, pp. 1117-1118.

Three borides of zirconium have been reported: ZrB, $ZrB_2$, and $ZrB_{12}$. The phase relationships, ranges of stability, and some physical properties of these compounds are described.

GLASS, J. J. See abs. 355.

290. GLASSENBERG, M., AND BERGER, M. J. Producing Titanium Alloy Castings. Am. Foundryman, vol. 25, No. 5, May 1954, pp. 107-112.

A furnace for melting and casting titanium has been developed, and a number of industrially important castings have been produced in zircon shell molds, dry silica-sand molds, and graphite molds. Details are given for furnace construction and zircon shell molds.

291. GLEN, J. W., AND PUGH, S. F. Effect of Phase Transformations on the Orientation of Zirconium Crystals. Acta Met., vol. 2, May 1954, pp. 520-529.

The orientation relations suggested by Burgers for the phase change in zirconium are used to deduce the possible orientations that can arise after 1 or 2 transformations starting from either a hexagonal or a body-centered-cubic lattice; their relative probability is assessed, assuming that at each stage all possible transformations are equally probable. The results of this analysis are compared with the known behavior of zirconium and titanium crystals and rolled zirconium strip; it appears that a first transformation is determined only by the orientation relations, but the second is not, for the original orientation almost invariably returns. The possible reasons for this are examined; one which has so far received little attention is that all simple dislocations in the parent phase can only return to simple dislocations after a second transformation if the original orientation returns. The reasons for the observed texture of crystal-bar zirconium are discussed, and experiments are suggested to indicate the importance of the various factors.

292. GOETZEL, C. G., AND WAGNER, R. B. Progress Report for May 1, 1950 to

July 31, 1950. Sintercast Corp. of America, NYO-687, Aug. 1, 1950, 12 pp.

A literature survey was made on methods for the production of zirconium carbide and on previous work done on cemented zirconium carbide bodies. Initial production of zirconium carbide from the oxide and hydride were found to be the most favorable methods. Two initial series of cold-pressed, sintered bars of commercial-grade zirconium carbide with 5 percent nickel were completed. Design activities were commenced with the development of a suitable vacuum or atmosphere hot-pressing apparatus.

293. GOETZEL, C. G., AND WAGNER, R. B. Progress Report for Aug. 1, 1950 to Oct. 31, 1950. Sintercast Corp. of America, NYO-688, Nov. 1, 1950, 24 pp.

The production of zirconium carbide from zirconium oxide was further developed to the point where uniform 1,000-gram batches of the carbide, containing 9 to 10 percent combined carbon and less than 0.5 percent free carbon, are now being produced. Recarburization, in vacuum, of this product for the purpose of increasing the combined carbon content was also undertaken. Cemented zirconium carbide test specimens, containing 10 and 20 percent iron and nickel, were produced, and some of their physical properties tested. An investigation of the influence of hot-pressing and cold-pressing and sintering-process variables on some of the physical properties of the test specimens was completed, and a vacuum recarburization furnace for zirconium carbide production constructed.

294. ___. Progress Report for Nov. 1, 1950 to Jan. 31, 1951. Sintercast Corp. of America, NYO-689, Feb. 1, 1951, 19 pp.

An investigation of the effect of particle-size distribution and milling media on some properties of cemented zirconium carbide with 10 percent nickel binder was carried on. A series of tests on the stability of cemented zirconium carbide bodies, containing various binders, at 1,000° C. in still air was made.

295. ___. Progress Report for Feb. 1, 1951 to May 31, 1951, and Final Report for May 1, 1950 to May 31, 1951. Sintercast Corp. of America, NYO-690, June 1, 1951, 16 pp.

This report also constitutes a final report, summary, and final-data evaluation of the experimental results obtained during the entire investigation carried on under this contract. The work concerned itself with the production and determination of some physical and chemical properties of cemented zirconium carbide bodies with metallic binders, such as iron and nickel and some of their alloys, by several powder metallurgical processes.

296. GOFMAN J. W. Studies With Colloids Containing Radioisotopes of Yttrium, Zirconium, Columbium, and Lanthanum. I. Chemical Principles and Methods Involved in Preparation of Colloids of Yttrium, Zirconium, Columbium, and Lanthanum. Radiation Lab., Univ. California, AECD-2057, Apr. 21, 1948, decl. June 16, 1948, 8 pp.; Jour. Clin. Lab. Med., vol. 34, No. 3, March 1949, pp. 297-304.

Colloids incorporating radioisotopes are useful in studying the selective localization of such isotopes in bone marrow, liver, and spleen. Colloids of zirconium, columbium, yttrium, and lanthanum have been chosen for study of selective localization of colloids because of the availability of radioisotopes of a wide range of nuclear properties and because of the comparative ease with which controlled variations in chemical structure and particle size of colloids containing these elements may be used. The methods for preparing zirconium and yttrium colloids of various chemical types and ranges of particle size are described. A discussion of some of the chemical principles of these preparative methods is given.

See also abs. 297.

297. DOBSON, E. L., GOFMAN, J. W., JONES, H. B., KELLY, L. S., AND WALKER, L. J. Studies With Colloids Containing Radioisotopes of Yttrium, Zirconium, Columbium, and Lanthanum. II. Controlled Selective Localization of Radioisotopes of Yttrium, Zirconium, and Columbium in the Bone Marrow, Liver, and Spleen. Radiation Lab., Univ. California, AECD-2055, Apr. 21, 1948, decl. June 16, 1948, 9 pp.

Studies with several colloids containing radioisotopes of zirconium, columbium (niobium), and yttrium have shown that the biological distribution of such materials depends upon the nature of the colloidal particles. Colloids of zirconium of relatively large particle size show rapid disappearance from the blood stream ($T_{1/2} = 30$ seconds to 1 minute) and are deposited primarily in the liver and spleen. Colloids of intermediate particle size, both of zirconium and yttrium, disappear much more slowly from the blood stream ($T_{1/2} = 30$ to 80 minutes) and are deposited primarily in the bone marrow and spleen, the liver acquiring only one-third the specific activity of marrow. Both types of colloids once deposited show no significant change in distribution pattern, at least over 2- to 4-week periods, and only slow excretion from the body.

GOLDBLATT, M. See abs. 308.

298. GOLDEN, L. B., SCHLAIN, D., LANE, I. R., JR., ACHERMAN, W. L., AND MACE, W. Corrosion Studies on Titanium and Zirconium Metals. Bureau of Mines Monthly Rept. NP-3568, September 1951, 8 pp.

An investigation of titanium and zirconium metals and their alloys was initiated in June 1947 to obtain quantitative data on the corrosion resistance to acids, bases, salts, and various organic compounds.

299. GOLDEN, L. B., ACHERMAN, W. L., AND MACE, W. Corrosion Studies on Titanium and Zirconium Metals. Bureau of Mines Quart. Rept. October-December 1953, 6 pp.

Progress report on an investigation initiated in June 1947 to obtain quantitative data on the corrosion resistance of titanium and zirconium metals and their alloys to acids, bases, salts, and organic compounds.

300. GOLDHABER, M., der MATEOSIAN, E., SCHARFF-GOLDHABER, G., SUNYAR, A. W., DEUTSCH, M. AND WALL, N. S. Isomeric State of $Y^{89}$ and the Decay of $Zr^{89}$. Massachusetts Inst. Technol., AECU-1474, 1951, 4 pp.

The production of $Y^{89m}$ by excitation with fast neutrons has been demonstrated in a very pure cadmium-covered sample of $Y_2O_3$ exposed to fast neutrons from the Brookhaven reactor. A strong 0.92 Mev. gamma-ray activity with a half life of 16 ± 3 seconds was found. An activity with gamma rays of the same energy and a half life of 13 ± 2 seconds was extracted from $Zr^{89}$, which showed a 0.91 Mev. gamma ray and a 0.51 Mev. annihilation radiation. Careful research failed to produce any evidence for other gamma rays ascribed to $Zr^{89}$ by Hyde and O'Kelley (UCRL-1064). About 1.3 times as many nuclear gamma rays as X-rays and about 4 times as many gamma rays as positrons were found in $Zr^{89}$ decay (TID-3010).

301. GOLDSCHMIDT, H. J. Structure of Carbides in Alloy Steels. Part. I. General Survey. Jour. Iron and Steel Inst. (London), vol. 160, December 1948, pp. 345-362.

This paper gives an account of X-ray work on carbides likely to occur in alloy steels, especially high-speed steels. It is mainly concerned with the structure of carbides formed by iron, chromium, tungsten, and molybdenum, but these are considered as part of a broader systematic survey of carbide-forming tendencies of alloying elements and their relation to crystal structure. A brief account is given of the relevant metal-carbon systems. The carbide structures are described and discussed, and an attempt is made to correlate them with their stability in the presence of given elements.

See also abs. 647.

GOLLOP, G. E. See abs. 49.

302. GONG, J. K., MILNE, W. L., AND COHN, S. H. Studies on the Treatment of Internal Radioactive Contamination. IV. Effect of Zirconium Citrate and EDTA on the Distribution and Excretion of a Mixture of Long-Lived Fission Products. U. S. Naval Radiological Defense Lab., USNRDL-426, Dec. 24, 1953, 16 pp.

The effects of zirconium citrate and sodium EDTA on the distribution and excretion of an injected mixture of long-lived fission products were investigated. The mixture contained the fission products that present the most serious health hazard from the chronic internal-irradiation viewpoint.

303. GOOD, R. C. Effects of Alloys in Cast Iron. Am. Foundrymen's Assoc., vol. 1, No. 8, August 1930, pp. 15-28.

After tracing briefly developments in the use of alloys in cast iron, describes the effects of varying percentages of carbon, silicon, phosphorus, sulfur, manganese, chromium, nickel, vanadium, and other elements on both chemical and physical properties of gray iron alloys. Also discusses possibilities in the use of the new alloy zirconium.

GOODMAN, C. See abs. 767.

304. GOODWIN, J. G., AND TOMBAUGH, R. W. Development and Production of Heavy-Walled Back-Extruded Zircaloy-2 Cups. Westinghouse Elec. Corp., WAPD-131, Oct. 29, 1955, 46 pp.

Describes the development of methods for the back extrusion of heavy-walled Zircaloy-2 cups. Discusses bar-stock preparation; development at Scaife Co., Aluminum Company of America, Wyman-Gordon Co., and Bettis, and production of the cups at Bettis; and recommends procedure for the production of back-extruded heavy-walled Zircaloy-2 cups.

GOODWIN, R. J. See abs. 616.

305. GORDON, N. E., JR., AND JACOBS, R. M. Spectrographic Determination of Impurities in Zirconium and Hafnium. Anal. Chem., vol. 25, No. 11, November 1953, pp. 1605-1608.

Recent developments in the production of zirconium and hafnium have made it necessary to develop methods for determining a large number of trace elements in these materials. This report presents a spectrochemical method for the determination of 22 elements found in zirconium and hafnium metals and oxides. Filings of the metal, or pulverized oxides, are taken and loaded into cratered graphite electrodes. The sample is then volatilized in either an alternating- or direct-current arc, depending on the elements of interest, and the resulting spectra are photographed and evaluated by conventional techniques. Some of the standards were obtained from the Massachusetts Institute of Technology and the New Brunswick Laboratories of the Atomic Energy Commission; others were synthesized from pure oxides of the base material and analytical grade reagents. Ten parts per million of most of the impurities can be determined with an accuracy of ±30 percent.

GORE, V. See abs. 191.

306. GORE, V., AND DHAR, N. R. Change of Viscosity of Sols and of Precipitating Concentrations of Electrolytes With Their Purity and the Change of the Ratio of Precipitating Concentrations With the Temperature of Coagulation. Jour. Indian Chem. Soc., vol. 6, 1929, pp. 641-652.

Results are recorded on the change of viscosity with the purity of ferric, stannic, ceric, zirconium, and thorium hydroxides and for arsenious sulfide, antimony sulfide, cupric ferrocyanide, Prussian blue, uranium ferrocyanide, mastic, and gamboge sols. Investigation was made into the influence of temperature on the ratio of precipitation concentrations of univalent and bivalent ions on some sols.

307. GOULD, B. S. Effects of Thorium, Zirconium, Titanium and Cerium on Enzyme Action. Proc. Soc. Exptl. Biol. Med., vol. 34, 1936, pp. 381-385.

Discusses results of a series of experiments upon the effects of thorium, zirconium, and titanium, and also cerium, a rare-earth metal, which shows many physiological properties in common with these others, upon the activity of amylase, invertase, phosphatase, and trypsin. The salts employed were thorium nitrate, cerium nitrate, zirconium nitrate and titanous chloride, which was allowed to oxidize and must be considered as tetravalent titanium.

GOULDEN, R. See abs. 70.

308. GRAVES, E. R., RODRIGUES, A. A., GOLDBLATT, M., AND MEYER, D. I. Preparation and Use of Tritium and Deuterium Targets. Los Alamos Sci. Lab., AECU-207, undated, decl. May 10, 1949, 16 pp.

Methods are described for preparing Ta-H and Zr-H targets for economic use of tritium. Ratios of hydrogen isotope to metals of about 1.0 were obtained. The use of these targets under deuteron bombardment is discussed.

GREEN, A. T. See abs. 646, 659.

GREENWALD, H. See abs. 105, 106, 107, 108.

309. GREENSFELDER, B. S., AND VOGE, H. H. Catalytic Cracking of Pure Hydrocarbons. Cracking of Naphthenes. Ind. Eng. Chem., vol. 37, No. 11, November 1945, pp. 1038-1043.

Cracking 11 naphthenes containing 6 to 18 carbon atoms was studied over a silica-zirconia-alumina catalyst. It was found that naphthenes are very susceptible to the action of the catalyst and that both the ring and any side chains contribute to the total cracking. The rate of cracking increases rapidly with increased molecular weight. Secondary reactions of isomerization and saturation play an important part in determining the final products. Catalyzed cracking at 500° proceeds at about 1,000 times the rate of thermal cracking, and there are significant differences in the product distributions.

310. ___. Catalytic Cracking of Pure Hydrocarbons - Cracking of Olefins. Ind. Eng. Chem., vol. 37, No. 10, October 1945, pp. 983-988.

Cracking 7 aliphatic olefins, 2 diolefins, 2 cyclic olefins, and 2 aromatic olefins over a silica-zirconia-alumina catalyst at 350°-500° C. was studied. The principal conversions of aliphatic mono-olefins were isomerization, cracking, saturation, and formation of higher boiling materials and coke. Diolefins and aromatic olefins were extensively saturated and transformed to higher-boiling materials and coke. Catalytic and thermal cracking of olefins at 400°-500° C. are compared. The catalyzed reactions, which are of the order of 1,000-10,000 times as fast, yield larger fragments, involve much more isomerization, and lead to greater saturation of product.

311. GREENWOOD, H. W. Powder Metallurgy and Heat-Resisting Alloys. Engineer, vol. 187, Apr. 1, 1949, pp. 349-351.

The melting points are covered for zirconium carbide, zirconium boride, and zirconia.

312. GRIFFITH, R. H., AND HILL, S. G. Catalysis in Hydrocarbon Chemistry. Part IV. Adsportion of Hexane on Catalysts. Trans. Faraday Soc., vol. 33, 1937, pp. 405-407.

Presents comparative data for the adsorption of hexane on a large number of catalysts at temperatures between 20° and 450°. Discusses activated adsorption, which can be detected in many cases, and its relation to catalyst activity.

313. GRIMALDI, F. S., AND WHITE, C. E. Quercetin as Colorimetric Reagent for Determination of Zirconium. Anal. Chem., vol. 25, No. 12, December 1953, pp. 1886-1890.

Methods described in literature for the determination of zirconium are generally designed for relatively large amounts of this element. A good procedure using colorimetric reagent for the determination of trace amounts is desirable. Quercetin has been found to yield a sensitive color reaction with zirconium suitable for the determination of from 0.1 to 50 gamma of zirconium dioxide. The procedure developed involves the separation of zirconium from interfering elements by precipitation with p-dimethylaminoazophenylarsonic acid prior to its estimation with quercetin. The quercetin reaction is carried out in 0.5N hydrochloric acid solution. Under the operating conditions, it is indicated that quercetin forms a 2-to-1 complex with zirconium; however, a 2-to-1 and a 1-to-1 complex can coexist under special conditions. Approximate values for the equilibrium constants of the complexes are $K_1 = 0.33 \times 10^{-5}$ and $K_2 = 1.3 \times 10^{-9}$. Seven National Bureau of Standards samples of glass sands and refractories were analyzed, with excellent results. The method described should find considerable application in the analysis of minerals and other materials for macro as well as micro amounts of zirconium.

314. GROSSE, A. V. Office of Naval Research High Temperature Project. 3rd Progress Rept., May 1, 1950 to Dec. 1, 1950. Research Inst., Temple Univ., NP-3361, Dec. 26, 1950, 68 pp.

Zirconium metal has been burned in a $ZrO_2$ pot in substantial quantities. The vapor pressure of zirconium metal is very low, and thus one can obtain very high temperatures in a concentrated spot before the metal vaporizes appreciably. The melting point of the product of combustion, $ZrO_2$, is one of the highest known (3,000° C.). The zirconium seemed to burn in a crystal-clear pool of $ZrO_2$, and the light of the reaction seemed to come from submerged layers. The approximate temperature recorded on a pyrometer was 3,100° K. These temperatures are only preliminary, since substantial absorption of the radiation may have taken place (TID-3010).

315. GROSSE, A. V., AND IPATIEFF, V. N. New Metal Halide Catalysts for Hydrocarbon Reactions. Jour. Organic Chem., vol. 1, 1937, pp. 559-566.

New metal halide catalysts, including beryllium chloride, titanium tetrachloride, zirconium tetrachloride, hafnium tetrachloride, thorium tetrachloride, columbium pentachloride, and tantalum pentachloride, have been found for hydrocarbon reactions. The ethylation of benzene with these catalysts and the nature of products obtained have been described.

GRUBER, B. A. See abs. 3.

316. GULBRANSEN, E. A., AND ANDREW, K.F. Crystal Structure and Thermodynamic Studies on the Zirconium-Hydrogen Alloys. Jour. Electrochem. Soc., vol. 101, No. 9, September 1954, pp. 474-480.

The phase diagram of zirconium-hydrogen alloys was studied on alloys prepared at low temperature and for alloys in the composition range of $ZrH_{0.025}$ to $ZrH_{1.965}$. Decomposition pressure studies were made over composition range and for a series of temperatures. Results of these measurements were in complete agreement with crystal-structure studies on the major phases. Results show presence of two major hydride phases, namely, the delta- and epsilon-phases as described by Hägg. No evidence was found for either the gamma- or delta-phases of Hägg, although the latter phase was found only at high temperature by Hägg. The epsilon-phase was found to have a wide range of homogeneity from $ZrH_{1.965}$ to about $ZrH_{1.65}$. The delta-phase was found to have a composition near $ZrH_{1.50}$

and a range of homogeneity from $ZrH_{1.4}$ to $ZrH_{1.56}$. A new minor transitional phase was found having the face-centered tetragonal structure and existing only in the presence of alpha-zirconium and delta-phases. It has been designated as the gamma-phase since its composition is probably near that of Hägg's gamma-phase. The free energy of formation of the delta-phase in contact with alpha-zirconium containing hydrogen was determined from decomposition pressure data.

317. GULBRANSEN, E. A., AND ANDREW, K. F. Diffusion of Hydrogen and Deuterium in High Purity Zirconium. Jour. Electrochem. Soc., vol. 101, No. 11, November 1954, pp. 560-566.

Kinetics of the reaction of zirconium with pure hydrogen and dueterium was studied for 60°-250° C., $H_2$ pressures of 1.1-5.0 cm. mercury, and composition range Zr-$ZrH_{1.70}$, using a vacuum microbalance method. The reaction was shown to be diffusion-controlled with diffusion occurring from a surface of constant concentration into a heterogeneous system.

318. ___. Mechanism of the Reaction of Hydrogen With Zirconium. I. Role of Oxide Films, Pretreatments and Occluded Gases. Jour. Electrochem. Soc., vol. 101, No. 7, July 1954, pp. 348-353.

Previous studies have shown the reaction of zirconium with hydrogen to be sensitive to surface preparation, surface films, heat-treating cycles, cold working of the metal, and nonmetallic impurities. Experiments were made on the rate of reaction of high-purity zirconium with pure hydrogen, using a sensitive microbalance method and an all-glass and ceramic vacuum system to minimize contamination. The effect of a preliminary vacuum-heating cycle on rate of reaction with hydrogen at 150° C. was studied by varying the temperature of the vacuum-heating cycle from 150° to 700° C. Samples having the room-temperature oxide showed only a slow rate of reaction, while samples heated to 700° C. for 1 hour showed a rate of reaction 7,700 times as great. Results also showed that the oxide film was effectively removed by heating in a vacuum for 1 hour at 500° C. A study was made of the thickness and nature of the oxide film. Thus, the film formed in air at room temperature was more resistant to hydrogen attack than thicker oxides formed at higher temperatures. Studies on the effect of small quantities of oxygen and nitrogen in solid solution indicate only minor effects. Results suggest that considerable revision is necessary in concepts of the mechanism of the hydrogen reaction on metals.

319. ___. Reactions of Metals in High Vacua. Jour. Phys. and Colloid. Chem., vol. 53, 1949, pp. 690-711.

The nature of chemical reactions occurring in vacuum and at high temperature on various metals is considered. These reactions are grouped into three classes: Those that form a gas as a result of a reaction, those that react with gases in the vacuum, and those that exchange one gas for another as a result of chemical reaction. Equilibria calculations are made where data are available on the reactions for the metals zirconium, tungsten, iron, chromium, and magnesium. The various reactions are discussed as sources and sinks in high-vacuum technique. An apparatus is described for studying these reactions at temperatures to 1,200° C. and at pressures at $10^{-6}$ mm. of mercury or better. A new type of high-temperature vacuum-furnace tube is described; this tube can be sealed to Pyrex and is vacuum tight at 1,200° C. Results are presented on the following problems: The vacuum oxidation of zirconium, tungsten, molybdenum, and mild steel; the formation of carbon monoxide by the reaction of carbon in the metal with the surface oxide for the alloy Nichrome vanadium; the volatilization of molybdic oxide and tungstic oxide and the oxidation and evaporation of magnesium.

320. ___. Reactions of Zirconium, Titanium, Columbium, and Tantalum With the

Gases, Oxygen, Nitrogen, and Hydrogen at Elevated Temperatures. Trans. Electrochem. Soc., vol. 96, No. 6, December 1949, pp. 364-376.

A systematic study of the kinetics of the reactions, including a study of the time, temperature, and pressure variables. The reaction rates are studied by the vacuum microbalance method, and the surface structures by the electron diffraction method. The data are correlated with fundamental diffusion and solution processes. Diffusion constants and energies of activation are calculated where possible, and a comparison is made of the several reactions for the different metals.

GURUSWAMY, S. See abs. 639.

## H

321. **HACKERMAN, N., AND WILLBANKS, O. L., JR.** Electrochemical Polarization of Zirconium in Distilled Water. Univ. Texas, Tech. Rept., 1954, 18 pp.

The cathodic polarization curve for zirconium in air-saturated distilled water at 40° C. was determined in the current density range $3.0 \times 10^{-7}$ to $1.0 \times 10^{-3}$ amp./cm$^2$. At low-current densities the reaction was the reduction of dissolved molecular oxygen to hydroxyl ions, its limiting diffusion current being about $5 \times 10^{6}$ amp./cm$^2$. The formation of a zirconium hydride film was the reaction proposed to explain a plateau in the curve, which had a constant potential of -0.30 volts versus SCE and a limiting current of $1.0 \times 10^{-4}$ amp./cm$^2$. X-ray diffraction data, time-potential curves, observations, and other evidences substantiated this possibility. Above $1.0 \times 10^{-4}$ amp./cm.$^2$ hydrogen evolution occurred, and the curve followed a Tafel relationship, the slope being -0.14 volts. The hydrogen overvoltage at 1.0 ma./cm.$^2$ was 0.75 volts. The open-circuit potential of zirconium in air-saturated distilled water at 40° C., was determined to be +0.16 volts versus SCE. The anodic polarization curve for zirconium in air-saturated distilled water at 40° C., was determined in the current density range from $1.0 \times 10^{-5}$ to $3.0 \times 10^{-3}$ amp./cm.$^2$. The potential rose in a linear fashion with the logarithm of current density, the slope being 0.07 volts.

322. **HADFIELD, R.** Refractory Materials. Trans. Faraday Soc., vol. 12, 1917, pp. 86-115.

A general coverage of the subject of refractories; discusses the shortcomings and the need for more extensive research.

323. **HAENDLER, H. M., AND ROBINSON, D. W.** Ammonium Pentafluorozirconate (IV) and Its Monohydrate. Jour. Am. Chem. Soc., vol. 75, No. 15, Aug. 5, 1953, p. 3846.

Ammonium pentafluorozirconate, $NH_4ZrF_5$, has been reported as one of the intermediate products of the thermal decomposition of ammonium heptafluorozirconate, $(NH_4)_3ZrF_7$. Attempts to grow single crystals of the pentafluorozirconate from solution for X-ray structural studies led to the discovery of its monohydrate. Experimental data and results are discussed.

324. **HAENDLER, H. M., WHEELER, C. M., JR., AND ROBINSON, D. W.** Thermal Decomposition of Ammonium Heptafluorozirconate (IV). Univ. New Hampshire, NYO-3158, Jan. 28, 1952, 5 pp.

A study of the thermal decomposition of ammonium heptafluorozirconate, $(NH_4)_3ZrF_7$, using the technique of differential thermal analysis. The decomposition proceeds in three distinct stages, $(NH_4)_3ZrF_7 \rightarrow (NH_4)_2ZrF_6 \rightarrow Nh_4ZrF_5 \rightarrow ZrF_4$. The temperature of decomposition is a function of the pressure.

325. **HAGIWARA, Z.** Studies on the Separation of the Rare Earths and Their Accompanying Elements. Part I. Consideration on the Separation of the Rare Earths, By Using the Hydrolysis of a Buffered Solution. Tohoku Univ. Technol. Repts., vol. 17, No. 2, 1953, pp. 58-69.

Describes the hydrolysis of buffered solution, containing urea, ammonium salt, and organic acid, to utilize separation of rare earths and their accompanying elements such as zirconium and thorium.

326. **HAGIWARA, Z.** Studies on the Separation of the Rare Earths and Their Accompanying Elements. Part II. Precipitation of Rare Earths, Thorium, and Zirconium From Homogeneous Solution. Separation of Thorium and Zirconium From Some Lanthanons. Tohoku Univ. Technol. Repts., vol. 17, No. 2, 1953, pp. 70-76.

Outlines a study on the precipitation of the rare earths, thorium and zirconium, from a homogeneous solution and the possibilities for the effective separation of these elements. Describes the separation of thorium and zirconium from the lanthanide series.

327. **HAKOMORI, S.** Reactions of Several Metallic Ions in the Presence of Organic Acids. Tohoku Imp. Univ. Sci. Repts., 1st series, vol. 20, 1931, pp. 736-763.

The reaction of molybdenum, titanium, vanadium, iron, chromium, aluminum, copper, nickel, cobalt, uranium, beryllium, lead, zirconium, and manganese were investigated in the presence of oxalic, citric, malic, or succinic acid by measuring the electrical conductivity, by spectrographic, ultramicroscopic, and colorometric observations, and by colloid-chemical treatment.

328. **HALDAR, B. C., AND SARKAR, P. B.** Note on the Investigation of Radioactive Mineral Zircon to Determine Its Geological Age. Sci. and Culture, vol. 11, November 1945, p. 271.

Chemical analysis of Travancore zircon indicates a hafnium content of about 1 percent. Travancore zircon shows very little radioactivity.

**HALIM, F. M. A.** See abs. 93, 94.

329. **HALL, A. R., AND WATT, W.** Bend Strength of Sintered Zirconium Carbide. Royal Aircraft Estab., ATI-99915, RAE-TN/Met. 137, December 1950, 20 pp.

Describes a resistance-heated hot press for sintering carbides under pressure in graphite dies. States results of bend-strength determinations at room temperature 1,050° and 1,600° C. for sintered compacts of zirconium carbide, also electrical-resistivity values at room temperature. The bend-strength determinations show a considerable scatter, the majority within the range 11-15 t.s.i. The maximum strength is reached before complete sintering occurs if the degree of sintering is judged by the electrical resistivity of the specimens. There is no drop in the bend strength of sintered zirconium carbide at 1,050° and 1,600° C. nor evidence of plastic flow under stresses of short duration at these temperatures.

330. **HALL, M. N. A., MARTIN, S. L. H., AND REES, A. L. G.** Solubility of Hydrogen in Zirconium and Zirconium-Oxygen Solid Solutions. Trans. Faraday Soc., vol. 41, 1945, pp. 306-316.

A study of the solubility of hydrogen in zirconium and in zirconium that contains oxygen in solid solution to the extent of 50 atom-percent has been made isothermally over a range of temperatures up to 1,000° C. and at pressures up to one atmosphere, rigid precautions being taken to eliminate surface contamination of the metal by oxide or nitride films. The isotherms exhibit critical phenomena, such as are observed in the palladium-hydrogen system, but, judging from the asymmetric disposition of the two-phase region and from the observed effects of oxygen on the shape of the isotherms, they must involve more than one dissolution process. The results also reflect the existence of the known lattice transition in zirconium.

331. **HAM, J. L.** Introduction to Arc-Cast Molybdenum and Its Alloys. Trans. ASME, vol. 73, August 1951, pp. 723-732.

Discusses the need for addition of alloying elements. Preliminary selection of appropriate alloying elements was based on their vapor pressures and known or expected solid solubility limits. Curves show the solid solubility limits of silicon, aluminum, iron, cobalt, and nickel in molybdenum at various temperatures, as determined by the measurement of lattice parameters of arc-cast samples and showing the effects of beryllium, aluminum, silicon, titanium, vanadium, chromium, iron, cobalt, nickel, zirconium, columbium, tantalum, and tungsten on the hardness of molybdenum at various temperatures. Regardless of which alloying element is used, there appears to be a limit to the increase in hardness that can be tolerated without causing difficulty in hot-working by the techniques applied so far. The effects of several of the alloying elements on the rate of work-hardening and on the temperatures of softening and recrystallization were studied, using a series of alloys that were extruded.

332. HAMILTON, J. G. Metabolism of the Radioactive Elements Created By Nuclear Fission. New England Jour. Med., vol. 240, No. 22, June 2, 1949, pp. 863-870.

Data on the oral absorption, principal organ of retention and accumulation in the rate of elimination from that organ of $Pu^{239}$, $Np^{239}$ and the long-lived fission products: $Sr^{89}$, $Sr^{90}$, $Ba^{140}$, $I^{131}$, $Cs^{135}$, $Y^{91}$, $La^{140}$, $Ce^{141}$, $Ce^{144}$, $Pr^{143}$, $Pm^{147}$, $Zr^{95}$, $Nb^{95}$, $Ru^{103}$, $Ru^{106}$, $Te^{129}$, and $Xe^{133}$, in the rat after parenteral and oral administration. Radioautographic studies, with special reference to skeletal accumulation, are summarized. (TID-3010)

333. HAMJIAN, H. J., AND LIDMAN, W. G. Sintering Mechanism Between Zirconium Carbide and Columbium. Nat. Advisory Comm. Aeronau., NACA TN-2198, October 1950, 29 pp.

The sintering mechanism of a zirconium carbide, columbium (niobium) ceramal (12.5 percent by weight of columbium), was investigated. Specimens were prepared by hot-pressing, and effects of sintering temperature and time at temperature were investigated. A bonding study was also made of a hot-pressed zirconium carbide specimen and columbium powder. The mechanism of sintering was found to be one in which columbium atoms diffuse into the zirconium carbide lattice, displace zirconium atoms, and form columbium carbide and zirconium metal.

HANSEN, M. See abs. 402, 501, 540, 671.

334. HANSEN, R. S. Adsorption Separation of Zirconium and Hafnium. Ames Lab., Iowa State Coll., AECU-842, Nov. 17, 1950, 7 pp.

An adsorption purification of zirconium from hafnium has been discovered. Most satisfactory results have been obtained from the preferential adsorption of hafnium from a methanol solution of zirconium and hafnium tetrachlorides by silica gel. Other solvents have been investigated, as well as effects of concentration, flow rate, and gel properties. Concentration of adsorbed hafnium to 30 to 60 percent products in good yields has been achieved by differential stripping.

335. HANSON, A. O., DUFFIELD, R. B., KNIGHT, J. D., DIVEN, B. C., AND PALEVSKY, H. Thresholds for Photo-Neutron Reactions in Manganese, Zinc, Zirconium, Molybdenum, Cadmium, Praseodymium, Neodymium, Gold, Mercury, Thallium, and Lead. Phys. Rev., vol. 76, 1949, pp. 578-579.

Measurements on thresholds for photoneutron reactions using X-rays from the 22-Mev. betatron.

336. HARDING, H. E. Toxicology of Zircon. Preliminary Report. British Jour. Ind. Med., vol. 5, 1948, pp.73-76.

No record has been found in literature of the toxicology of zircon, $ZrSiO_4$, the use of which in industry as a substitute for silica is likely to increase. Suspensions of finely ground Travancore zircon were made intravenously into a rabbit, intraperitoneally into cavies, and intratrachelly into rats. In none of these animals was there any evident interference with health or growth. Histological examination of tissues obtained several months later suggests that zircon is a singularly inert substance.

337. **HARKINS, W. D., AND JURA, G.** Surfaces of Solids. XIII. A Vapor Adsorption Method for the Determination of the Area of a Solid Without the Assumption of a Molecular Area and the Areas Occupied by Nitrogen and Other Molecules on the Surface of a Solid. Jour. Am. Chem. Soc., vol. 66, August 1944, pp. 1366-1373.

An extremely simple method has been developed for calculating the surface area of a solid from the adsorption isotherm. This consists in plotting log p or log $p/p_0$ against the reciprocal of the square of the volume adsorbed $(1/v^2)$. Generally, a straight line, which represents a condensed film, is obtained over a considerable range of the plot. The area (sigma) of the solid is given by the equation $\Sigma = Ks^{1/2}$, where s is the slope of the straight line and k is a constant for a given adsorbed vapor at a given temperature. The value of k, as determined by our absolute method is: Nitrogen at -195.8°, 4.06; water at 25°, 3.83; n-butane at 0°, 13.6; and n-heptane at 25°, 16.9. The apparatus used for the determination of an adsorption isotherm is described.

**HARRIS, S. P.** See abs. 90.

338. **HARRISON, D. E., McKINSTRY, H. A., AND HUMMEL, F. A.** High-Temperature Zirconium Phosphates. Jour. Am. Ceram. Soc., vol. 37, No. 6, June 1954, pp. 277-280.

The existence of two zirconium phosphate compounds has been established. The "normal" phosphate, $ZrP_2O_7$, has a reversible inversion at 300° C. and dissociates to the zirconyl compound, $(ZrO)_2P_2O_7$, at 1,550° C. with the simultaneous loss of $P_2O_5$ as vapor. The room-temperature form of $ZrP_2O_7$ is cubic with refractive index 1.657 ± 0.003. The zirconyl compound has a stable existence to temperatures around 1,600° C. and is characterized by a very low linear thermal-expansion coefficient.

339. **HARTMANN, I., NAGY, J., AND BROWN, H. R.** Inflammability and Explosibility of Metal Powders. Bureau of Mines Rept. of Investigations 3722, 1943, 44 pp.

Fifty-three powder samples of 14 different metals and 2 alloys were tested. Minute concentrations of dispersions of the powders in air needed to permit ignition from a high-voltage, low-energy spark ranged from 0.02 to approximately 0.5 ounces per cubic foot. The wall temperature required in a heated furnace to ignite dispersions of the powders (except zirconium) in air was 315° (reduced iron) to 900° (chromium and milled iron). Zirconium ignited at room temperature under some conditions. The minimum energy required for ignition by spark of dispersions of a number of powders is so small as to be insignificant in practice. If the ignition temperature is reached there can hardly fail to be sufficient energy for ignition. Data are given on relative inflammabilities determined (1) in a furnace at 700° and (2) ignited by a spark; the order is not identical nor is it the same as ignition temperature. Maximum pressure and rates of pressure rise in explosions are reported. There is a wide range of values. Maximum pressure, 72 p.s.i., measured during an explosion of magnesium powder, was reached only 0.05 seconds after ignition, a rate of pressure rise of almost 5,000 p.s.i. per second. Zirconium, magnesium and its alloys, aluminum and titanium, were the most hazardous. Reduced and carbonyl iron, manganese, zinc, silicon, tin, and antimony are intermediate in danger. Cadmium, copper, chromium, lead, and milled iron have a low order of inflammability and explosibility.

Titanium, zirconium, and magnesium and its alloys ignited in pure $CO_2$. For other metals, maximum allowable O in O-$CO_2$ mixtures was 3-18 percent. No dust ignited in pure nitrogen, and permissible oxygen content was higher than in O-$CO_2$ mixtures. Minimum ignition temperatures of quiescent layers of dust are generally below those of dispersions. Minimum energy for ignition of dust layers is minute for several powders. Quiescent layers of zirconium, magnesium, and magnesium alloys burned vigorously in $CO_2$ and $N_2$ when heated sufficiently (Chem. Abs.).

340. **HARTMANN, I., NAGY, J., AND JACOBSON, M.** Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium and Their Hydrides. Bureau of Mines Rept. of Investigations 4835, 1951, 16 pp.

Summarizes the results of experiments on 22 samples of titanium, zirconium, thorium, uranium, and hydrites of these metals.

341. **HARWOOD, J. J.** Minutes of the Symposium on Corrosion for February 3 and 4, 1949. Nat. Acad. Sci., NP-3092, undated, 174 pp.

Zirconium is not attacked appreciably by HCl, $HNO_3$, glacial AcOH, formic, monochloreacetic acids, acetic anhyride, and 6 percent $H_2SO_3$. Negligible corrosion rates were observed for methyl, ethyl, and furfural alcohols, respectively; zirconium is resistant to $H_2SO_4$ to 80-percent strength at 35° C. and to 60 percent $H_3PO_4$ at 100° C. The addition of small concentrations of $HNO_3$ to concentrated $H_2SO_4$ has no effect on inhibiting the corrosion of zirconium in $H_2SO_4$. Zirconium is unattacked by 20 percent NaCl solution at 100° C. and shows minor attack at 35° C. by a solution of 10 percent NaCl and 5 percent $FeCl_3$. The tensile strength varies from 115,000 to 140,000 p.s.i., the yield strength from 80,000 to 120,000 p.s.i., and elongation from 1.0 to 2.5 inches; the Brinell hardness is 85, and the density 6.5 (TID-3010).

342. ___. New Structural Metals. Prod. Eng., vol. 21, No. 10, October 1950, pp. 96-102.

Summarizes the properties, availability, production, and fabrication of the refractory metals zirconium, titanium, columbium, molybdenum, tantalum, tungsten, and chromium. The melting points and densities of these metals are given. Information is included on preliminary alloys of these metals.

343. **HATSCHEK, R. L.** Rolling: Firm Likes "Tough Jobs." Iron Age, vol. 172, No. 5, July 30, 1953, p. 35.

A discussion of strip rolling zirconium to extra-thin gages.

**HAUBER, E. S.** See abs. 783.

344. **HAUSNER, H. H.** Formation of Metal From Its Compound During Sintering. Powder Met. Bull., vol. 6, No. 1, April 1951, pp. 41-43.

The general rule in powder metallurgy is that pure metal powders are the most suitable raw materials for the production of sintered metals. Tests, however, indicate that in some cases the use of metal compound powders is more favorable for the production of sintered metals than the use of pure metal powders. Tests were made with zirconium and zirconium hydride powders, respectively, and the results obtained with these two powders show a superiority of zirconium hydride powder over zirconium powder for the production of sintered zirconium.

**HAYES, E. T.** See abs. 18.

345. **HAYES, E. T., ROBERSON, A. H., AND PAASCHE, O. G.** Zirconium-Titanium System: Constitution Diagram and Properties. Bureau of Mines Rept. of Investigations 4826, 1951, 11 pp.

The zirconium-titanium system was investigated over the entire range of compositions from 100 percent zirconium to 100 percent titanium, using both graphite-melted and arc-melted alloys. Thermal analysis, resistivity measurements, melting-point studies, and X-ray analysis were used to determine the phase relationships. Zirconium and titanium are soluble in all proportions and form two series of solid solutions - the beta (cubic) form at elevated temperatures and the alpha (hexagonal) form. The beta transformation point is depressed to a minimum at 50 atomic-percent and 535° C. The liquidus reaches a minimum at 67 atomic-percent zirconium and 1,610° C.

HAYES, J. C. See abs. 256.

HAYES, R. S. See abs. 273.

HAYMOND, H. R. See abs. 277.

HAZRA, G. D. See abs. 759.

HEIN, R. E. See abs. 799.

HENDERSON, A. W. See abs. 285.

346. HENDERSON, A. W., AND HIGBIE, K. B. Improved Method for Obtaining High-Purity Zirconium and Hafnium Oxides. Jour. Am. Chem. Soc., vol. 76, No. 22, 1954, p. 5878.

A procedure for the purification of zirconium or hafnium oxides of high-purity is proposed. $ZrOCL_2.8H_2O$ is the compound recrystallized from an acetone-HCl mixture to effect purification. The yields of zirconyl chloride during each recrystallization step are from 96 to 99 percent. The $ZrOCl_2.8H_2O$, soluble in half its weight of water, is recrystallized from an acetone-hydrochloric acid mixture with a minimum normality of 4.5. The ratio of $ZrOCl_2.8H_2O$ to acetone is 2.4. The average zirconium starting material contained the following impurities: 0.3 percent iron, 0.1 percent silicon, 100-1,000 p.p.m. titanium and aluminum, and less than 100 p.p.m. copper. The final product after 5 recrystallization steps gave a spectrographic analysis of 20 p.p.m. each of aluminum, iron, copper, and silicon, and less than 0.5 p.p.m. boron. No other elements except hafnium were detected. This procedure is believed to equal or exceed any of the existing methods for the purification of either metal oxide.

HENDRIX, R. C. See abs. 360.

HENRY, D. E. See abs. 656, 657.

HENRY, E. C. See abs. 781.

347. HERTY, C. H., III. Solid State Reactions: Investigation of Color and Compound Formation in the Systems $ZrO_2$-$SiO_2$-$V_2O_5$ and $Cr_2O_3$-$Al_2O_3$-ZnO; Diffusion of Chromium Oxide Through Alumina. Dissertation Abs., vol. 14, No. 3, March 1954, p. 475.

The purpose of this research was to study the reactions occurring between finely divided solids at high temperatures but at temperatures well below the melting point of the solids. This involved investigation of color development and compound formation in ceramic oxides. The effects of particle size, temperature, time, and composition were noted in two ternary systems, the $ZrO_2$-$SiO_2$-$V_2O_5$ system and the $Cr_2O_3$-$Al_2O_3$-ZnO system. The diffusion of $Cr_2O_3$ into $Al_2O_3$ at five different temperatures, ranging from 1,260° to 1,595° C., using aluminas of varying bulk densities, was studied as a separate problem.

348. HEVESY, G. Discovery and Properties of Hafnium. Chem. Rev., vol. 2, No. 1, 1925, pp. 1-41.

This report gives data on the discovery of hafnium and the quantum theory of atomic structure, methods for separating hafnium from zirconium, properties of hafnium, methods for determination of the hafnium content of zirconium, the atomic weight of zirconium and the hafnium content of the zirconium preparations used in its determination, and the occurrence of hafnium in nature; and it compares zirconium and hafnium with the other elements.

349. ___. Discovery of Hafnium. Current Sci. (India), vol. 5, November 1936, pp. 236-240.

Detailed discussion of the history of the discovery of hafnium.

350. HEVESY, G. Note on the Chemistry of Hafnium. Chem. News, vol. 127, No. 3301, July 1923, pp. 33-34.

A brief coverage of the chemistry of hafnium.

See also abs. 163.

351. HEVESY, G., AND JANTZEN, V. T. Hafnium Content of Zirconium Ores. Jour. Am. Chem. Soc., vol. 123, 1923, pp. 3218-3223.

Procedures and results of the X-ray analysis of zirconium.

352. ___. Hafnium Content of Zirconium Ores. Chem. News, vol. 128, No. 3346, May 30, 1924, pp. 341-342.

Discusses the occurrence of hafnium in zirconium ores.

353. ___. Separation of Hafnium From Zirconium. Chem. News, vol. 127, No. 3221, December 7, 1923, pp. 353-355.

A detailed description of the preparation of hafnium by the double-flouride method.

354. HEVESY, G., AND LEVI, H. Artificial Activity of Hafnium and Some Other Elements. Kgl. Danske Videnskab. Salskab, Mat fys. Medd., vol. 15, No. 11, 1937, 18 pp.

The irradiation of hafnium with neutrons has been shown to produce a radioactivity with a half life of 55± 7 days and which may be ascribed to $^{181}_{72}$ hafnium. The intensity of the beta rays emitted is reduced to half its initial value by an aluminum foil having a weight of 16 mgm./$cm^2$.

355. HEWETT, D. F., AND GLASS, J. J. Two Uranium-Bearing Pegmatite Bodies in San Bernardino County, California. Am. Mineral., vol. 38, No. 11-12, November-December 1953, pp. 1040-1050.

Two uranium-bearing pegmatite bodies have been discovered recently in San Bernardino County, Calif. Examination shows that each one contains small amounts of uncommon minerals that are composed largely of titanium, niobium, and uranium. However, the mineral assemblages are different for each. One body, in the Cady Mountains, contains, in addition to the common feldspars and quartz, the rare minerals betafite, niobian anatase, and cyrtolite (Metamict zircon). The other pegmatite body at Pomona Tile quarry near Rock Corral contains euxenite and an unidentified uranium-bearing mineral as well as the rare-earth minerals monazite and allanite and several common minerals.

HIBBARD, W. R., JR. See abs. 423, 596.

HIBDON, D. T. See abs. 90.

HICKS, H. G. See abs. 826.

356. HICKMAN, J. W. Oxide Films Formed on Metals and Binary Alloys. An Electron Diffraction Study. AIME, Tech. Pub. 2483, December 1948, 18 pp.

Generally, it is impossible to predict the oxide that will be observed on the basis of the thermodynamic stabilities of the several possible oxides or of the sizes of the ions that may form. Oxides of some elements are not observed in the outer surface of the oxide layer. Among these are oxides of silicon and zirconium. Some alloys show the presence of oxides of only one of the metals, indicating that ions of the other metal have much lower rates of formation and diffusion in the temperature region studied. Other alloys show the presence of oxides of one of the metals at low temperatures, while oxides of the other metals appear at elevated temperatures. In these instances the rates of formation and diffusion of the two metallic ions vary in a different manner with temperature. Complex oxides containing more than one metal do not form on the surfaces of most alloys. Exceptions to this are alloys that contain iron, chromium, or nickel (TID-3010).

357. **HIEMSTRA, S. A.** Baddeleyite From Phalaborwa, Eastern Transvaal. Am. Mineral., vol. 40, Nos. 3 and 4, March-April 1955, pp. 275-282.

The rare mineral baddeleyite occurs at Phalaborwa in the Eastern Transvaal. It has a density of $D^{25}{}_4 = 5.739 \pm 0.005$. The optical properties are:

$$\begin{aligned} \alpha &= 2.136 \pm 0.005 \\ \beta &= 2.236 \pm .008 \\ \gamma &= 2.243 \pm .008 \\ 2V\alpha &= 30^\circ \pm 1/2^\circ \\ X \wedge c &= 13^\circ \end{aligned}$$

An X-ray diffraction pattern and a chemical analysis are given.

HIGBIE, K. B. See abs. 346.

HILL, S. G. See abs. 312.

HILLIARD, A. See abs. 772.

358. **HILLIARD, A., AND STOTT, V. H.** Cleavage in Heat-Treated Zircon. Trans. British Ceram. Soc., vol. 48, 1949, pp. 143-152.

Crystals of zircon sand usually exhibit little or no cleavage. Certain heat treatments produce cleavage, and the phenomenon is influenced both by the nature of the heat treatment and by the impurities in the sand. This is due to corresponding influences on the tendency of zircon to decompose into silica glass and zirconia. Such decomposition starts on crystal planes and causes cleavage.

359. **HINCHCLIFFE, M. R.** Zircon Sand. Metal Ind., vol. 83, No. 22, Nov. 27, 1953, pp. 437-440.

Discusses the merits of zircon sand as a core material for severe casting conditions. Gives procedures for the preparation of zircon core sand. Compares the relatively new shell-molding method and traditional molding methods.

360. **HINERMAN, D. L., HENDRIX, R. C., AND WELLER, C. V.** Toxicity, Distribution, Excretion, and Morphologic Effects of Hafnium Sodium Mandelate in Rats. Am. Jour. Clinical Pathology, vol. 24, No. 2, February 1954, pp. 150-152.

Discusses the results of experimentation in the administration of hafnium sodium mandelate to rats. Hafnium as a neutral solution of hafnium sodium mandelate was found to be without systemic toxicity for white rats.

361. **HIRSH, F. R., JR., AND RICHMYER, F. K.** Relative Intensities of Certain L-Series X-ray Satellites in Cathode-Ray and in Fluorescence Excitation. Phys. Rev., vol. 44, No. 12, 2d series, Dec. 15, 1933, pp. 955-960.

Using a specially designed X-ray tube, the authors have measured the relative intensity of satellites and their parent $L\alpha_1$ line, for both cathode-ray and fluorescence excitation for the elements zirconium, molybdenum, ruthenium, rhodium, palladium, and silver. Cathode-ray excitation was by 20-kv. electrons. Fluorescence excitation was caused by radiation from a target of silver bombarded by 20-kv. electrons. A photographic method is used in which spectrograms, moll microphotometric records, and density plots are made, from which it is possible to obtain the relative intensity of the satellites and their parent $L\alpha_1$ line. The results of fluorescence excitation suggest that LM ionization is the most probable origin of the $L\alpha$ satellites. On the other hand, the rapid variation in relative intensity of the satellites with atomic number for cathode-ray excitation seems to indicate that the peripheral electron structure of the atom plays a fundamental role in the production of satellites. The magnitude of the integrated intensity of the group of satellites accompanying $L\alpha$ varies from 10 to 70 percent of the intensity of the parent line, depending on the element and the method of excitation.

362. **HOCH, M., NAKATA, M., AND JOHNSTON, H. L.** Vapor Pressures of Inorganic Substances. XII. Zirconium Dioxide. Jour. Am. Chem. Soc., vol. 76, No. 10, May 20, 1954, pp. 2651-2652.

The vapor pressure of $ZrO_2$ has been determined by the method of Knudsen, between 2,014 and 2,290° K. $ZrO_2$ vaporizes undissociated as $ZrO_2(g)$, the heat of vaporization being $\Delta H^{\circ}_{298} = 153.6 \pm 1$ kcal. The vapor pressure can be represented by the equation $\log (34{,}383/T) - 7.98 \times 10^{-4}T + 11.98$. The heat of dissociation of $ZrO_2$ (g) into gaseous atoms was found to be $D_o = 365 \pm 5$ kcal.

363. **HODGE, W.** Production and Properties of Nonferrous Metals. Metals Rev., vol. 21, No. 11, November 1948, pp. 3, 5.

Developments in the rare metals, copper, zinc, lead, titanium, and zirconium.

364. **HOFFMAN, C. A.** Preliminary Investigation of Zirconium Boride Ceramals for Gas-Turbine Blade Applications. Nat. Advisory Comm. Aeronau., RM E52L15a, Apr. 10, 1953, 13 pp.

Zirconium boride $ZrB_2$ ceramals were investigated for possible gas-turbine-blade application. Included in the study were thermal shock evaluations of disks, preliminary turbine-blade operation, and observations of oxidation resistance. Thermal shock disks of the following three compositions were studied: 97.5 percent $ZrB_2$ plus 2.5 percent boron by weight, 92.5 percent $ZrB_2$ plus 7.5 percent boron by weight, and 100 percent $ZrB_2$. Thermal shock disks were quenched from temperatures of 1,800°, 2,000°, 2,200° and 2,400° F. The life of turbine blades containing 93 percent $ZrB_2$ plus 7 percent boron by weight was determined in gas-turbine tests. The blades were run at approximately 1,600° F. and 15,000 to 26,000 r.p.m. The thermal-shock resistance of the 97.5 percent $ZrB_2$ plus 2.5 percent boron ceramals compares favorably with that of TiC plus cobalt and TiC plus nickel ceramals. Oxidation of the disks during the thermal-shock evaluation was slight for the comparatively short time (8.3 hour) up through 2,000° F. Oxidation of a specimen was severe, however, after 100 hours at 2,000° F. The turbine blade-performance evaluation of the 93 percent $ZrB_2$ plus 7-percent boron composition was preliminary in scope; no conclusions can be drawn.

**HOGG, B. G.** See abs. 279.

365. **HOLLADAY, J. W., AND KURA, J. G.** Melting and Fabrication of Zirconium. Chem. Eng. Prog. Symposium Series, vol. 50, No. 11, 1954, pp. 23-30.

Because of its reactivity with atmospheric gases and all known crucible refractories, zirconium must be consolidated by the special technique of arc melting in a furnace equipped with a water-cooled copper crucible. For production of large-scale ingots, a consumable electrode is preferable to an inert electrode. Zirconium can be forged and rolled readily in air with conventional equipment. It can be extruded to rod and tubing and can also be spun, cupped, and drawn. Machining characteristics are similar to those of aluminum. Joining is achieved by soldering, brazing, and welding. Zirconium may be contaminated by oxygen, nitrogen, carbon, or hydrogen during processing. Oxygen, nitrogen, and carbon strengthen zirconium at room temperature, but the strengthening is lost when it is heated to relatively low temperatures; consequently, zirconium has good hot-working characteristics. It is not contaminated during the short time required to complete hot-working operations. Resistance of zirconium to corrosion is excellent in acid alkali and metal chlorides. Its resistance to hydrychloric and phosphoric acids is outstanding, but it is not resistant to sulfuric acid in concentrations greater than 80 percent. New nonreactor uses of ductile zirconium will probably be based on its excellent corrosion resistance.

**HOLMES, H. P.** See abs. 463, 465.

366. **HOLMES, L. A.** Raw Materials for Ceramic Colors. Jour. Canadian Ceram. Soc., vol. 22, 1953, pp. 135-139.

Discusses the increasing importance of ceramic colors and includes a list of raw materials for specific colors.

367. HOLNESS, H. S. Tannin as a Reagent in Qualitative Analysis. Anal. Chim. Acta., vol. 3, 1949, pp. 290-294.

All bases should form tannin-absorption complexes by reciprocal flocculation, provided the correct pH is obtained. Those having colors easily recognized are included in a table (tantalum, zirconium, tin, germanium, niobium, titanium, bismuth, thorium, antimony, molybdenum as ($MoO_4$) - cerium, $Fe^{+3}$, vanadium as ($VO_2$) -, uranium as ($UO_2$)++, copper, tungsten as ($WO_4$), and tungsten as silico-, phospho- or borotungstate). (TID-3010)

368. HOLNESS, H., AND LAWRENCE, K. R. Scheme of Semi-Micro Qualitative Analysis for Thirty-Nine Elements. Analyst, vol. 78, No. 927, June 1953, pp. 356-362.

The classical hydrogen sulfide scheme of qualitative analysis is modified to include all the elements likely to be encountered in modern analytical practice. The behavior of tungsten in forming complex acids is recognized and allowed for. An existing method of phosphate removal is modified and expedited to deal both with phosphates and complex tungstates. The details given apply only to the semimicro technique for 2 to 5 mg. of material in about 3 ml. of solution.

369. HOLNESS, H., AND PATE, B. D. Precipitation of Silica by Tannin. Anal. Chim. Acta., vol. 3, 1949, pp. 315-319.

Examines the precipitation of silica by tannin from chloride solution. Precipitation was never complete, the maximum being 96 percent from a solution 0.075 normal in ammonia. Separations of zirconium and tin from silica in acid chloride solution and of tin from acid oxalate solution were shown to be clean only if the initial acidity was higher than 0.4 normal. Separations of titanium from silica in both acid chloride and acid oxalate solution were never clean, as titanium required a very low acidity before precipitation was complete.

HORIE, T. See abs. 779.

HORN, R. C. See abs. 64.

370. HORTON, A. D. Spectrophotometric Determination of Zirconium. Anal. Chem., vol. 25, No. 9, September 1953, pp. 1331-1333.

Development work is being continued on the use of 2-(2-hydroxy-3,6-disulfo-1-napthylazo)benzenearsonic acid [1-(o-arsonophenylazo)-2-naphthol-3,6-disulfonic acid, Thoron,] as a spectrophotometric reagent. Its previous use for determination of thorium (IV), and experimental results on its formation of complexes with tin (IV), titanium (IV), hafnium (IV), and zirconium (IV) indicates that it may form complexes with all quadrivalent metal ions. The reagent has been used successfully for determination of zirconium. The method covers a range of 10 to 100 gamma of zirconium with a precision within 5.7 percent in the 10-gamma range and 2.9 percent in the 100-gamma range. The method is simple and rapid and does not require a skilled analyst. The reagent, although complex, is now available commercially and requires little preparation. There are very few interferences which cannot be reduced to noninterfering states or removed from the sample without loss of zirconium.

371. HORTON, W. S. Progress in Vacuum Fusion Analysis at KAPL. Knolls Atomic Power Lab., KAPL-666, Jan. 3, 1952, 31 pp.

Describes the apparatus designed and constructed for vacuum fusion analysis. Diagrams show the arrangement and individual components. The apparatus appears to be unique in the use of glass-mercury solenoid valves instead of stopcocks or U-type mercury cutoffs. The blank rate obtained is as satisfactory as those from other laboratories. The results on National Bureau of Standards samples of

"Cooperative Steels" compare favorably with those reported by the cooperators. Some vanadium samples were analyzed, and the results made it possible to show that one sample was inhomogeneous. Some data on oxygen recoveries from chromium-chromic oxide mixtures appear to indicate an optimum operating temperature of about 1,600° C. when molten iron is used as a flux.

HOSHINO, S. See abs. 725.

HOTOP, W. See abs. 434.

HOWARD, A. M. See abs. 246.

372. HOWE, R. M. Refractories for Electric Furnace. Chem. and Met. Eng., vol. 23, No. 25, Dec. 22, 1920, pp. 1215-1218.

Describes the properties of refractory brick and the raw materials employed in their manufacture and reviews the many factors involved in the efficient general use of refractories.

HOWES, H. L. See abs. 593.

HOWLETT, L. E. See abs. 538.

373. HUDSWELL, F. Preparation of Hafnium-Free Zirconium, the Chemical Research Laboratory Method and Other Methods. Atomic Energy Research Est., England, AERE-C/M-54, Feb. 8, 1950, 4 pp.

Discusses methods noted recently, particularly the Chemical Research Laboratory method. Makes suggestions for large-scale preparation of zirconium.

374. HUFFMAN, E. H., AND IDDINGS, G. M. Zirconium Thenoyltrifluoroacetonate: Solubility and Extraction. Radiation Lab., Univ. California, UCRL-377, June 17, 1949, decl. Nov. 17, 1953, 10 pp.

Solubilities of zirconium thenoyltrifluoroacetonate have been determined in anhydrous benzene at 20°, 30°, and 40° C., in 0.01, 0.02, 0.04, and 0.08 molar thenoyltrifluoroacetone in benzene at 20° C., in benzene saturated with water at 20° C. and in 0.02 molar thenoyltrifluoroacetone in benzene in contact with 2 molar perchloric acid at 20° C.

375. HUFFMAN, E. H., IDDINGS, G. M., OSBORNE, R. N., AND SHALIMOFF, G. V. Extraction of Zirconium and Hafnium With Various Fluorinated Beta-Diketones. Radiation Lab., Univ. California, UCRL-2536, Apr. 5, 1954, 15 pp.

The distribution ratios and equilibrium constants for the extraction of zirconium and hafnium from 4 M perchloric acid with various combinations of fluorinated beta-diketones and organic solvents have been determined. The separation factors, $K^1_{Zr}/K^1_{Hf}$, found for this acidity were: 2 thenoyltrifluoroacetone in benzene, 25; 2-thenoyltrifluoroacetone in o-dichlorobenzene, 16; benzoyltrifluoroacetone in benzene, 18; isovaleroyltrifluoroacetone in benzene, 13; isovaleroyltrifluoracetone in h-hexane, 13.

376. HUFFMAN, E. H., AND LILLY, R. C. Anion Exchange of Complex Ions of Hafnium and Zirconium in H61-Hafnium Mixtures. Jour. Am. Chem. Soc., vol. 73, June 1951, pp. 2902-2905.

The elution of complex ions of zirconium and hafnium from an anion exchange resin with mixtures of hydrochloric and hydrofluoric acids has been studied in two different concentration ranges. Differences in the dependence of the distribution coefficient upon the concentrations of chloride ion, hydrogen ion, and hydrofluoric acid have been noted for the two ranges, and some possible ionic equilibria are discussed in connection with the data.

HUME, D. N. See abs. 519.

HUMENIK, M., JR. See abs. 443, 600.

HUMMEL, F. A. See abs. 338.

377. HUMMERS, W. S., TYREE, S. Y., JR., AND YOLLES, S. Thermal Decompositions

of Addition Compounds of Zirconium Tetrachloride and Hafnium Tetrachloride With Esters. Univ. North Carolina, AECU-1293, 1951, 2 pp.

A method for the thermal decomposition of metal halide-ester addition compounds to ascertain the difference in the rate of decomposition of hafnium and zirconium compounds; delineates the mechanism of the reaction.

378. HUMPHREY, G. L. Heats of Formation of Tantalum, Niobium, and Zirconium Oxides and Tantalum Carbide. Jour. Am. Chem. Soc., vol. 76, No. 4, Feb. 20, 1954, pp. 978-980.

The heats of formation of tantalum pentoxide, niobium (columbium) pentoxide, zirconium dioxide, and tantalum carbide were measured by combustion calorimetry. The results are, respectively, -488.8 ± 0.5, -455.2 ± 0.6, -261.5 ± 0.2 and -38.5 ± 0.6 kcal/mole at 298.16° K. Corresponding free-energy values were calculated.

379. HUPPERT, P. A. Introduction of Lithium Compounds in Titania Enamels. Finish, vol. 5, No. 11, November 1948, pp. 19-23, 68.

Describes a variety of tests carried out by introducing chemically precompounded lithium compounds in titanium-bearing, super-opaque, cover-coat enamels used either in the mill or in the batch composition of the frit. Discusses the results of the most promising experiments, especially the influence of these lithium compounds on color and reflectance stability and on smelting and firing conditions.

380. HURLEY, P. M., AND FAIRBAIRN, H. W. Radiation Damage in Zircon: A Possible Age Method. Bull. Geol. Soc. Am., Vol. 64, June 1953, pp. 659-673.

The relationship has been studied between crystal-structure damage and total alpha-particle irradiation in zircon. The total irradiation was based on estimated or measured age times alpha activity, and the damage was determined by the change of the X-ray diffraction angle from the (112) plane as measured to .01° by X-ray spectrometer. The angle was found to be 35.635° (2θ) for completely undamaged material and to approach 35.1° asymptotically as the zircon had suffered increasing dosages of alpha irradiation and become metamict. The difference between the measured angle and 35.635° was found to equal 0.535 exp. $[-2.31 \times 10^{-16}$ alpha$]$ degrees, where $\alpha$ = total irradiation in alphas/mg. The results have been interpreted to indicate that $4.5 \times 10^3$ atoms are displaced per alpha disintergration and that the annealing rate is essentially zero at earth's surface temperature. The process appears to be usable for age measurement but generally limited to zircons of less than 500 alphas/mg./hr. activity. It was further found that the zircon became "half-metamict" after a radioactive energy release of 685,000 cal./gm., indicating that only a fraction of a percent of the energy can be stored in the structure as disordered atoms, the remainder being lost as heat. Observations on the high annealing rate of common rock minerals shows that the amount of energy capable of being stored in a rock by alpha damage is negligible in questions relating to petrogenesis and volcanism.

381. HUTTON, C. O. Final Technical Report, May 1, 1951 to June 30, 1953. Part 1. Studies of the Minor Constituents in Some California Beach Sands. Part 2. Optical and Chemical Studies of Minerals Containing Tantalum, Niobium, Titanium and Uranium as a Preliminary to Investigation of the Mineralogy of Some Idaho Placer Deposits. Stanford Univ., RME-3049, June 30, 1953, 55 pp.

An exhaustive mineralogical study of 135 samples of beach sands collected between the north end of Half Moon Bay and Pacific Grove, Calif., has been completed. A study of minerals in which tantalum and niobium are the dominant elements was begun. Nine pure samples were prepared from well crystallized materials by electromagnetic procedure, flotation in fused salts, and handpicking. Physical data have been determined, and differential thermal analyses have been made for these pure materials; their reactions to chemical reagents have been observed.

382. HYSLOP, J. F., STEWART, J., AND BURNS, N. Corrosion and the Fluxing of Refractory-Glass Mixtures. Trans. British Ceram. Soc., vol. 46, 1947, pp. 377-386.

A study of the refractory-slag cones for two bricks shows that the brick giving a large number of low viscosity cone below the testing temperature will be rapidly attacked, while the brick having a long range of viscous cones will be relatively resistant to the slag. Development of a technique for rapid testing shows that informative results can be obtained by using two briquettes set one on the other upon the refractory. The top briquette consists of 80 slag 20 brick and the bottom of 20 slag 80 brick. Fusion tests have been carried out using soda-lime, lead, and borosilicate glass with a variety of refractories. This method does not take into account the physical makeup of the brick, but it indicates the extent to which the refractory and the slag form low-melting and fluid, or viscous, reaction products.

## I

IDDINGS, G. M. See abs. 374, 375.

383. INDIAN AND EASTERN ENGINEERING. Symposium on Non-Ferrous Metal Industry in India. Vol. 114, No. 4, April 1954, pp. 477-485.

A survey of the resources of zirconium and titanium in India.

384. INGLES, J. C. Chemical Determination of Thorium in Ores. Canadian Chem. and Proc. Ind., vol. 35, May 1951, pp. 397-398, 400, 402, 404, 406.

Describes various methods for the separation of thorium from ores and the rare earths and covers the mandelic acid separation of thorium from zirconium.

IPATIEFF, V. N. See abs. 315.

385. IRON AGE. Uses of Zirconia in Steel Metallurgy. Vol. 101, May 16, 1918, pp. 1276-1277.

Presents facts on the occurrence, preparation, and properties of zirconia and its use as a refractory. Briefly covers the use of ferrozirconium in steel purification.

386. ___. Zirconium. Vol. 170, No. 15, Oct. 9, 1952, pp. 286-287.

Discusses potential uses including metal-to-glass seals and corrosion-resistant jobs.

387. ISHINO, T., AND OGAWA, Y. Extraction and Preparation of Zirconium Compounds From Zircon Ore by Wet Process. Osaka Univ., Technol. Repts., vol. 1, 1951, pp. 119-132.

A comprehensive report on the extraction of zirconium compounds from zirconium ore. The results show that the degree of decomposition of zirconium ore by alkali fusion was 95 percent in the following conditions, 4NaOH/ore = 3 (weight ratio = 2.5), temperature 700°-750° C., time of fusion 3 hours. The degree of extraction from zirconate with concentrated $H_2SO_4$ was about 99 percent at $2H_2SO_4/ZrO_2 = 2$. Treating zirconate with concentrated Hcl, a yield of about 99 percent at $2HCl/ZrO_2 = 2.5$ was obtained. When aqueous solution of $Zr(SO_4)_2$ was hydrolyzed with organic acid at pH = 4.7, the purity of $ZrO_2$ was 98.98 percent, and the yield 91.86 percent. Hydrolysis of $Zr(SO_4)_2$ solution by method of dilution and heating was incomplete; the degree of hydrolysis was about 50 percent. Pure $K_2ZrF_6$ free from titanium and iron was obtained by recrystallization; the purity was 99.91 percent, and the yield about 60 percent. Washing $ZrOCl_2.8H_2O$ with ether or ethanol was effective for removing iron, but the yield was lower.

388. IVEY, H. F. Anomalous Values of the Thermionic Emission Constant.

Phys. Rev., vol. 74, No. 8, 1948, pp. 983-984.

The thermionic emission constant, A, in the Richardson-Dushman equation,

$$I = AT^2 \exp(-e \phi /kT) \text{ is}$$

$$120 \text{ amp/cm}^2 \text{ deg}^2.$$

The author cites measurements of A that are less than this value on nickel, platinum, and zirconium to support the statement that clean metals yield values below this and infers that higher values are caused by unclean metal.

## J

JACKSON, J. H. See abs. 584.

389. JACOBS, C. W. F. Opacifying Crystalline-Phases Present in Zirconium-Type Glazes. Jour. Am. Ceram. Soc., vol. 37, No. 5, May 1954, pp. 216-220.

Various zirconium-type opacifiers were used in a group of glazes maturing in the range cone 04 to cone 11 and the crystalline phase producing opacity in these fired glazes was studied by elevated-temperature X-ray diffraction techniques. The results definitely show that zirconium silicate is the major crystalline phase that promotes opacity regardless of the zirconium opacifying agent added. The foregoing conclusion pertains only to the opacifying particle; this should not be construed to mean that other important characteristics of glazes do not vary with the form of zirconium addition.

390. JACOBS, C. W. F., AND BALDWIN, W. J. Effects of Zirconium-Type Opacifiers on Properties of Glazes. Jour. Am. Ceram. Soc., vol. 37, No. 6, June 1954, pp. 258-266.

The use of various zirconium-type opacifiers such as zircon, zirconia, and the alkaline-earth silicates of zirconium in fritted and raw glazes maturing in the range cones 06 to 04 and cones 9 to 11, respectively, and the properties of the resulting slips and fired glazes were investigated. Substitution of the various opacifiers was in each instance based on the molecular glaze composition. In the fritted glazes, maturing at cones 06 to 04, where the use of all types of zirconium opacifiers was not possible without altering the molecular composition, optimum properties were obtained with zircon. In the raw type of glazes maturing at cones 9 to 11, in which a greater variety of opacifier substitutions could be made, combinations of the alkaline-earth silicates of zirconium as opacifiers produced a marked improvement in slip properties and a definite reduction in opacifier segregation compared with glazes opacified with zircon or with zirconia. Use of the alkaline-earth silicates of zirconium did not impair other fired properties such as opacity, gloss, texture, and finish.

JACOBS, H. See abs. 103.

JACOBS, R. M. See abs. 305.

JACOBSON, L. See abs. 608, 773.

391. JACOBSON, L., AND OVERSTREET, R. Uptake by Plants of Plutonium and Some Products of Nuclear Fission Adsorbed on Soil Colloids. Soil Sci., vol. 65, 1948, pp. 129-134.

Barley and pea plants have been found to take up the fission elements yttrium, cerium, zirconium+columbium, tellurium, strontium, and the three valence states of plutonium, even when these elements are present in trace amounts and on the surfaces of clay or soil particles. For all the elements tested, the greatest fixation is in or on the roots. With the exception of strontium, translocation occurs only to a limited extent. The translocation of strontium is relatively large. Activity levels of 0.1 microcurie per gram soil are sufficient to cause very pronounced injury over a 3-month period.

JACOBSON, M. See abs. 340.

392. JACQUET, P. A. Electrolytic Polishing of Zirconium and Its Application to a Study of the Effects of Abrasion Upon the Structure of the Metal. Metallurgia, vol. 42, October 1950, pp. 268-270.

The difficulties attendant on the preparation, by normal metallographic procedures, of etched specimens of zirconium suitable for microscopic examination, emphasize the importance of electrolytic methods of polishing. This article deals briefly with the methods that have proved satisfactory and with their application to a study of the effect of abrasion on the structure of the metal.

JAFFEE, R. I. See abs. 255.

393. JAFFEE, R. I., AND CAMPBELL, I. E. Properties of Zirconium. Battelle Mem. Inst., NP-266, June 18, 1947, 24 pp.

A detailed literature survey of the physical, chemical, and other properties of zirconium, summarizing the known data on zirconium at the time of the report. The physical properties include tensile strength, elongation, shear strength, modulus of elasticity, and hardness. Fabrication data include rolling, wire drawing, welding, machinability, spinning and drawing, and bending. The chemical properties of zirconium include the action of $O_2$, $N_2$, $H_2$, halogens, carbon, silicon, boron, $H_2O$ vapor, and $NH_3$. Tabulated information is given on the corrosion resistance. Other information includes atomic properties, structure, and density. The electrical properties include the resistivity, temperature coefficient of resistivity, pressure coefficient of resistivity, superconductivity, magnetic susceptibility, photoelectric threshold, thermionic emission, electrical equivalence, and thermoelectric power. The thermal properties include the melting point, boiling point, linear coefficient of expansion, specific heat, and the coefficient of spectral emissivity. Applications of zirconium are also given (TID-3010).

JAHN, C. See abs. 700.

JANTZEN, V. T. See abs. 351, 352, 353.

394. JATKAR, S. K. K., AND VALVEKAR, R. K. Activity of Different Catalysts for Vapor Phase Esterification. Jour. Indian Inst. Sci., vol. 21A, 1937, pp. 449-454.

Comparative activities of different catalysts including zirconium oxides for vapor phase esterification equilibria of acetic acid by ethyl alcohol, have been studied at 150°. Potassium hydrosulfate and activated carbon have been found to be the best. In the case of both the catalysts, the maximum conversion observed is 94 percent and 89 percent of the equilibrium conversion at high space velocities, owing to the temporary poisoning of the catalyst mass by water vapor. Silica gel is the most unsuitable catalyst for esterification in vapor phase at 150°.

JEFFERYS, R. A. See abs. 641.

395. JENKINS, J. L. Ferroelectric Dielectrics Used in Voltage-Sensitive Capacitors. Elec. Mfg., vol. 54, No. 1, July 1954, pp. 125-129.

Voltage-sensitive barium titanate ceramics are being used in nonlinear capacitive circuit elements to perform functions of electronic tubes or magnetic amplifiers in dielectric amplifiers, multivibrators, and other circuits. Physical and electrical properties of these ferroelectric dielectric materials are reviewed.

396. JENKNER, K., AND BRODA, E. Some Upper Limits of Possible Alpha-Activity. Nature, vol. 164, No. 4166, Sept. 3, 1949, pp. 412-413.

Several heavy elements were tested for alpha decay. Photographic plates were impregnated with various ions by a bath in solutions of suitable salts. After drying and keeping for known times, the alpha tracks formed were counted usually in 1,000 to 2,000 fields of view under the microscope and identified among radioactive contaminants by measuring the track length. From the number of tracks counted, the half life was calculated. The following half lives (years x $10^{-15}$) were observed: Mo > 9, Rb > 17, Zr > 2, Cd > 6, Pb > 3, Bi > 3, Sm 0.0010, and Th 0.000014. (TID-3010)

397. JEWSBURY, A., AND OSBORN, G. H. Some Further Analytical Applications of Ammonium Benzoate. An Investigation Into the Uses and Limitations of Ammonium Benzoate for the Quantitative Estimation of Tin, Titanium, Zirconium, Thorium, Bismuth and Cerium and for Their Separation From Other Elements. Anal. Chim. Acta., vol. 3, 1949, pp. 642-655.

Zirconium in HCl or $HNO_3$ solution may be estimated by precipitation with ammonium benzoate at pH 1.0-1.5, using a mixed indicator and subsequently weighing as $ZrO_2$ after ignition. The precipitation is unaffected by thioglycollic acid in whose presence only aluminum, titanium, and thorium are precipitated. In the presence of thioglycollic acid the effects due to coprecipitation in presence of iron, cerium, and tin were small. If copper is present, this can be removed by precipitation of the zirconium in the absence of thioglycollic acid. In the presence of thioglycollic acid the copper comes down with the zirconium. Separations from aluminum, $cerium^{III}$, and $uranium^{IV}$ also are indicated in the presence of thioglycollic acid. A good separation from titanium was not obtained.

398. JOFFE, M. H., AND TEMPLE, L. A. Effect of Zirconium Citrate on the Distribution of Intravenously Administered Plutonium in the Dog. I. Preliminary Observations. Hanford Atomic Works, HW-28636, undated, pp. 92-97.

Plutonium IV and VI were removed up to 85 percent of the administered amount by prompt treatment with zirconium citrate at a level of about 100 mg./kg. The retention of plutonium by the dog varied only slightly with the valence state of the plutonium administered, and both plutonium IV and plutonium VI were preponderantly deposited in the liver and skeleton.

399. JOHANSEN, H. Studies Concerning the Thermal Decomposition of Zirconium Iodide. Univ. Oregon Thesis, June 1950, 53 pp.

This report gives the results of an investigation carried out to determine a possible means of converting pure anhydrous $ZrCl_4$ to $ZrI_4$. The zirconium tetraiodide was then to be used directly in van Arkel or thermal dissociation process for production of ductile zirconium. Several modifications of the van Arkel procedure for the thermal dissociation of zirconium iodide were investigated.

400. JOHNSON, C. M. Determination of Uranium, Zirconium, Chromium, Vanadium,and Aluminum in Steel, Parts I and II. Chem. and Met. Eng., vol. 20, No. 10, May 15, 1919, pp. 523-524; vol. 20, No. 11, June 1, 1919, pp. 588-589.

The innovation in these determinations is the removal of the bulk of the iron by partial neutralization of the acid solution by ammonia. Addition of ammonia is stopped after a slight reddish precipitate appears, and a few drops more cause the precipitate to darken. At this stage most of the iron is in solution and may be separated by filtration. Details are given for completing the analyses, including the gravimetric determination of zirconium as the phosphate.

JOHNSON, J. R. See abs. 174.

401. JOHNSON, W. A. New Metals for Nuclear Technology. Chem. and Eng. News, vol. 32, No. 19, May 10, 1954, pp. 1882-1887.

Discusses the potential of zirconium and its key role in the construction of thermal reactors and other atomic applications.

402. JOHNSON, W. R., AND HANSEN, M. Research on the Element Silicon and Silicon Alloys. Wright-Patterson Air Force Base, AF-TR-6383, June 1951, 133 pp.

Phase studies on the silicon-zirconium system. A eutectic has been found for $Si_2Zr$ which has 61.9 percent zirconium. The phase diagram is believed to be similar to $Si_2Mn$.

JOHNSTON, H. L. See abs. 12, 362, 740, 741, 742, 743.

403. JOHNSTONE, S. J. Minerals for Chemical and Allied Industries. Ind. Chem., vol. 25, April 1949, pp. 243-247.

The chemical industries and others closely allied to them have found use for increasing quantities of substances of mineral origin. In this article consideration is given to such minerals, including zircon.

JONES, A. See abs. 285.

JONES, H. B. See abs. 297.

404. JONES, J. B. Ultrasonics Applied to Solidification and Solid-State Transformation. Aeroprojects, Inc., AF-TR-6675, October 1951, 73 pp.

Ultrasonic energy was applied to 24S and 75S aluminum alloys after solution heat treatment, and the effect on age hardening evaluated, primarily by means of Rockwell hardness readings and tensile tests. The effects were small and indicated that high-intensity elastic energy retards precipitation hardening. Ultrasonic energy was applied to melts of pure zinc, a 3.5 percent magnesium-zinc alloy and magnesium-zirconium alloys. Grain refinement was accomplished and sounder ingots resulted from the use of ultrasonics. Zirconium sponge was alloyed with pure magnesium by the application of ultrasonics (TID-3010, supp. 1).

JONES, R. G. See abs. 287.

JONES, T. S. See abs. 607.

JONGEJANS, C. See abs. 804.

405. JOURNAL OF METALS. Alloys for the Steel, Iron, and Non-Ferrous Industries. Vol. 6, No. 4, April 1954, pp. 390-391.

Gives nominal composition of zirconium alloys in table form.

406. JOY, A. H. Absorption Lines Within the Hydrogen Emission of Mira Ceti. Astrophys. Jour., vol. 106, No. 2, September 1947, pp. 288-294.

On spectrograms taken with the high dispersion of the coudé spectrograph, most of the absorption minima within the emission lines of Mira Ceti may be identified with metallic lines of the reversing layer of the star. Sixty-five lines were thus assigned to 13 elements, and 4 other lines in H gamma were attributed to TiO. The measurements seem to furnish enough proof that the hydrogen producing the emission lines is at a lower level than the source of the numerous metallic-absorption lines of the star's atmosphere.

407. JUNCK, G. Refractories - the Backbone of Industry. Australasian Eng., June 7, 1948, pp. 91-93, 95, 145-149.

This report outlines the refractories industry today and its importance to industrial processing. Several refractory materials are reviewed, including zirconia and zircon.

JURA, G. See abs. 337.

JUREVIC, W. G. See abs. 3.

408. JURRIAANSE, T., PENNING, F. M., AND MOUBIS, J. H. A. Normal Cathode Fall for Molybdenum and Zirconium in the Rare Gases. Philips Research Repts., vol. 1, 1946, pp. 225-238.

Original from THE OHIO STATE UNIVERSITY

A reproducible and stable normal cathode fall for molybdenum and zirconium could be obtained by covering the wall of the tube with metal produced by sputtering the cathode. This blackening of all noncathodic parts is shown to be essential for the stability. The reproducibility is several volts for different tubes, and the stability is some tenths of a volt for 1,000 hours burning or resting.

## K

409. **KALISH, H. S.** Zirconium Now Fabricated by Powder Metallurgy Methods. Materials and Methods, vol. 37, No. 2, February 1953, pp. 101-103.

Sintered zirconium is readily cold worked, reduces machining costs, minimizes scrap loss, and simplifies alloying. This article presents the process, experimental data, and results.

410. **KALISH, H. S., AND MAZZA, E. N.** Evaluation of Dissociated Ammonia and Hydrogen Atmospheres for Sintering Stainless Steel. Jour. Metals, vol. 7, No. 2:2, February 1955, pp. 304-310.

The effect of sintering types 302, 302B, and 430 stainless-steel powder compacts in hydrogen and dissociated ammonia was investigated. It was found that sintering in dissociated ammonia resulted in as much as 0.5 weight-percent increase in the nitrogen content of stainless steel, even though the dissociation of the gas was complete. Sintering in hydrogen, on the other hand, reduced the nitrogen content of the stainless steel to less than 0.1 weight-percent. For 302-type stainless steel the low nitrogen content resulted in a material that was largely ferritic, whereas the high nitrogen content rendered the material fully austenitic. Sintering in dissociated ammonia resulted in lower density, generally lower tensile strength, less ductility, and higher hardness than sintering under equivalent conditions in hydrogen. The reduction of oxides on both stainless-steel and iron particles was found to be effected by hydrogen partial pressure in the sintering atmosphere. Compacting pressure was found also to effect oxide reduction during sintering.

411. **KAPITZA, P.** Change of Electrical Conductivity in Strong Magnetic Fields. Part I. Experimental Results. Proc. Roy. Soc. (London), Series A, vol. 123, 1929, pp. 292-341.

Describes some improvements on the method of measuring the change of resistance in strong magnetic fields. The change of resistance in a transverse field at room temperature, at temperature of solid $CO_2$ and ether, and at the temperature of liquid nitrogen has been studied in the following metals: Lithium, sodium, copper, silver, gold, beryllium, magnesium, zinc, cadmium, mercury, aluminum, gallium, indium, thallium, carbon, titanium, germanium, zirconium, tin, lead, thorium, vanadium, arsenic, antimony, bismuth, tantalum, chromium, molybdenum, tellurium, tungsten, manganese, iron, nickel, palladium, platinum, a gold-silver alloy, and $Cu_3As$. The change of resistance in a parallel field was measured for a few metals. It was found that in all the metals the change of resistance follows the same law, which can be expressed by a formula that fits the experimental results quite well. This formula gives a square law in weak fields and a linear law in stronger fields. It has been shown that the physical change produced in a conductor by hardening and annealing has a strong influence on the phenomenon of change of resistance. The influence of the impurities is also very marked and was studied. A comparison with the results of previous experimental researches is given.

412. **KARLSSON, N.** X-Ray Study of the Phases in the Silver-Zirconium System. Acta Chem. Scand., vol. 6, 1952, pp. 1424-1430.

The silver-zirconium system has been investigated by X-ray methods. Two intermediate phases have been found: Beta and gamma with the ideal compositions AgZr and $AgZr_3$. The ranges are narrow. The structure of the beta phase is of the B-11 type (isomorphous with γ-CuTi) and that of the gamma phase may be considered as a deformed L-12 ($AuCu_3$) type (isomorphous with $CuTi_3$ and $CuZr_3$). No solid solubility of zirconium in silver or of silver in alpha-zirconium could be detected.

KATCOFF, S. See abs. 120.

KATO, H. See abs. 591.

413. KATZ, L., BAKER, R. G., AND MONTALBETTI, R. Photoneutron Cross Sections of $Rb^{87}$, $Zr^{90}$, and $Mo^{92}$. Canadian Jour. Phys., vol. 31, 1952, pp. 250-261.

The photoneutron cross sections of the 50-neutron isotopes $Rb^{87}$, $Zr^{90}$, and $Mo^{92}$ have been measured as a function of photon energy. These cross sections exhibit the peaked-shape characteristic of photonuclear reactions. Peak values of 0.23, 0.27, and 0.14 barn at 17.5, 18.0, and 18.7 Mev., respectively, were found for these nuclei. The widths of all the curves at half maximum were about 6 Mev. In the case of zirconium and molybdenum the cross sections to the isomeric and ground states of the residual nuclei have been determined separately. The ratio of the cross sections, $\sigma$ ground/$\sigma$ isomeric, has been examined as a function of photon energy and is discussed in the light of the elementary analysis previously presented.

KAUFMAN, A. R. See abs. 511.

KAUFMANN, A. See abs. 258.

414. KEELER, J. H. Development of Zirconium-Base Alloys. 17th Quart. Rept. (Progress Rept. 18). G. E. Research Lab., SO-2513, RL-1036, Jan. 5, 1954, 11 pp.

Tensile tests were conducted on zirconium ternary alloys in air at room temperature and in vacuo at 500° C. Yield-stress and elongation data are presented. A stress-strain curve typical of many zirconium binary alloys tested at 500° C. is shown. Initial creep data for unalloyed zirconium and for a zirconium-aluminum binary alloy is given. Deformation and annealing textures for unalloyed, arc-melted, and cold-rolled zirconium are presented, as are annealing textures for two zirconium-aluminum alloys.

415. ___. Development of Zirconium-Base Alloys. 18th Quarterly Report (Progress Rept. 19). G. E. Research Lab., SO-2514, RL-1071, Apr. 5, 1954, 8 pp.

Tensile tests were conducted on zirconium ternary alloys in air at room temperature and in vacuo at 500° C. Tabulated data are presented. An alloy containing 3 atomic-percent aluminum and 1 atomic-percent molybdenum, after annealing on the beta region (950° C.), had the highest yield strength at 500° C., namely, 50,000 p.s.i. Creep-rupture data for unalloyed, annealed zirconium up to 500° C. are presented. The 1,000-hour rupture strength at 500° C. was estimated to be 7,000 p.s.i. The annealing texture for a 90-zirconium, 10-aluminum alloy, heat-treated in the alpha region (800° C.) consists of the basal plane in the rolling plane and [1010] direction in both the rolling and cross-rolling directions, a double texture.

416. ___. Development of Zirconium-Base Alloys. 19th Quarterly Report (Progress Rept. 20). G. E. Research Lab., SO-2515, RL-1124, July 5, 1954, 9 pp.

Tensile tests were conducted on zirconium ternary alloys in air at room temperature and in vacuo at 500° C. Tabulated data are presented. The alloys Zr + 3 Al + Mo, Zr + 5 Al + 1 Mo, and Zr + 3 Al + 5 Ta (atomic-percent) had yield strengths greater than 50,000 p.s.i. at 500° C. The compound $Zr_3Al$ was found to be ordered face-centered-cubic, of the $Cu_3Au$ type, with an $a_o$ = 4.372 ± 0.003 A. A summary of the report, "Preferred Orientations in Beta-Annealed Zirconium", is given.

417. KEELER, J. H. Development of Zirconium-Base Alloys. 20th Quarterly Report (Progress Rept. 21). G. E. Research Lab., SO-2517, RL-1191, Oct. 5, 1954, 3 pp.

Metallographic and X-ray pinhole-pattern data showed that unalloyed zirconium sheets annealed at 400° C. contained newly formed grains, although the deformation-like texture was predominant. Creep-rupture data for some zirconium binary alloys are reported, the 8 atomic-percent aluminum alloy exhibiting the greatest strength at 500° C. The deformation texture of the zirconium-3 atomic-percent tantalum alloy was found to be qualitatively similar to the deformation texture of unalloyed zirconium; whereas annealing at 900° C. produced a texture somewhat similar to that obtained for unalloyed zirconium annealed at 1,400° C.

418. ___. Development of Zirconium-Base Alloys. 21st Quarterly Report (Progress Rept. 22). G. E. Research Lab., SO-2519, 55-RL-1261, Jan. 5, 1955, 8 pp.

The preferred orientation in cold-reduced and in annealed sheets of a zirconium-3 atomic-percent chromium alloy was found qualitatively similar to unalloyed zirconium. A plot of d ln L/d in epsilon versus epsilon for early-maximum-load-type tensile curves showed deviation from a straight line and the beginning of localized necking at strains considerably beyond the strain for maximum load. The conclusions from research on zirconium-chromium alloys are presented. The short-time tensile characteristics of zirconium-molybdenum binary alloys are given. The presence of unstable, untransformed, body-centered-cubic phase in these alloys is thought to explain their tensile behavior.

419. ___. Development of Zirconium-Base Alloys. 22d Quarterly Report (Progress Rept. 23). G. E. Research Lab., SO-2520, 55-RL-1303, Apr. 5, 1955, 15 pp.

The stress-rupture characteristics of beta-annealed zirconium are essentially equivalent to those of alpha-annealed zirconium at room temperature and 300° C. the minimum creep rate is less and the rupture life is greater than for alpha-annealed zirconium. The 1,400° C. annealing texture of a meta-stable body-centered-cubic zirconium-alloy sheet containing 18 percent niobium (columbium) was (111) < 112 >. The Burgers orientation relation was found applicable to this alloy when transformed to the close-packed hexagonal phase. The tensile properties of zirconium-tantalum and zirconium-niobium binary alloys are summarized. For equivalent atomic percentages, tantalum and niobium strengthen zirconium less than does molybdenum but more than do iron or chromium.

420. ___. Development of Zirconium-Base Alloys. 23d Quart. Rept. (Progress Rept. 24). G. E. Research Lab., SO-2523, 55-RL-1405, July 5, 1955, 23 pp.

The short-time tensile properties of zirconium-aluminum, zirconium-silicon, and zirconium-aluminum-silicon alloys are given for the temperature range -195° to 500° C. The initial incremental strengthening of zirconium by aluminum and by silicon is much greater than later incremental amounts. The strengthening effects of the individual alloying elements silicon and aluminum are not additive when the elements are added simultaneously to zirconium. Small additions of silicon or aluminum are among the most potent strengtheners of the alloying elements examined in this program. However, subsequent additions of these two elements are not very effective in their strengthening. The tensile characteristics of beta-annealed iodide process zirconium are given for the temperature range -195° to 500° C. The tensile properties of chloride-process zirconium as a function of temperature and orientation in relation to rolling direction are reported. Stress-rupture time and stress-minimum creep-rate curves for binary alloys at room temperature and at 500° C. are given.

421. KEELER, J. H. Zirconium. Prod. Eng., August 1954, pp. 183-187.

The strength of zirconium is influenced by various metallurgical variables such as grain size and orientation, amount of strain in metal, structure as influenced by heat treatment, and impurities or alloying elements. These variables are discussed in detail in this report.

422. KEELER, J. H., AND GEISLER, A. H. Preferred Orientations in Beta-Annealed Zirconium. G. E. Research Lab., SO-2516, RL-1148, August 1954, 16 pp.

Preferred orientations in unalloyed zirconium and in a zirconium-niobium alloy were determined by the Geiger-counter spectrometer X-ray diffraction technique. Annealing unalloyed zirconium in the beta region just above the allotropic transformation temperature results in a reversion to the alpha-annealing texture on cooling to room temperature. With higher beta-annealing temperatures (through 1,200° C.), additional orientations predictable from the alpha-beta orientation relationship were obtained. Evidence of a cube texture in beta zirconium was observed on specimens annealed at 1,400° C. The cubic-zirconium, 18-percent-niobium alloy sheet was found to have textures very similar to those found in iron. No cube texture was observed in the alloy. Earlier work on cold-worked and alpha-annealed zirconium was reappraised to show a quantitative dependence of rotations on temperature and to identify spurious areas of some of the pole figures.

423. KEELER, J. H., HIBBARD, W. R., JR., AND DECKER, B. F. Textures of Rolled and Annealed Iodide Zirconium. Jour. Metals, vol. 5, No. 7, July 1953, pp. 932-936; vol. 6, No. 5, May 1954, pp. 699-700.

Textures of hot-rolled, cold-rolled, and cold-rolled-and-annealed zirconium sheets were determined by use of an X-ray spectrogoniometer. All textures showed a tilt of the basal planes ± 40° from the rolling plane about the rolling direction. Deformation textures showed the [1010] direction to be approximately in the rolling direction. After recrystallization, the [1120] direction was approximately in the rolling direction. This texture was sharpened by anealing above the allotropic transformation. Textures of sheet produced by alternately cold rolling and then annealing were less strongly oriented than sheets that underwent severe deformation without intermediate anneals. The discussion of this report is appended to the original report.

424. KEELER, J. H., AND MALLERY, J. H. Crystal Structure and Some Properties of the Compound, $Zr_3Al$. Jour. Metals, Vol. 7, No. 2:2, February 1955, p. 394.

The compound $Zr_3Al$ is of special interest since it is encountered as the precipitated phase in zirconium-rich alloys, and this report gives consideration to the crystal structure. X-ray data are included.

KEIGHTON, W. B. See abs. 515.

425. KEIM, C. P. Survey of Calutron Charge Materials for Stable Isotope Separation. Oak Ridge Nat. Lab., AECD-3309, Nov. 14, 1951, 9 pp.

Summarizes the calutron separation process. Successful charge-material and temperature-range data are given in table form for the various elements including zirconium.

426. KELLEY, G. L., AND MYERS, F. B. Notes on the Analysis of Alloys of Nickel and Zirconium. Jour. Ind. Eng. Chem., vol. 9, No. 9, 1917, p. 854.

This paper outlines a method for the analysis of an alloy containing carbon, nickel, iron, silicon, aluminum, zirconium, tungsten, and manganese.

427. KELLEY, K. K. Contributions to the Data on Theoretical Metallurgy,

VIII. The Thermodynamic Properties of Metal Carbides and Nitrides. Bureau of Mines Bull. 407, 1937, 66 pp.

Thermodynamic data relating to metal carbides and nitrides are collected and discussed with the view of obtaining usable heat and free energy of formation relations. Pertinent data are difficult to obtain experimentally and are rare; this fact necessitates frequent use of approximations and assumptions. $CH_4$ and $NH_3$ also are included, because some of the reactions considered involve these substances. The carbides considered are those of aluminum, calcium, chromium, cobalt, iron, manganese, molybdenum, nickel, silicon, sodium, thorium, titanium, tungsten, uranium, vanadium, and zirconium. The nitrides include those of aluminum, barium, beryllium, boron, calcium, cerium, chromium, iron, lanthanum, lithium, magnesium, manganese, molybdenum, silicon, strontium, tantalum, thorium, titanium, uranium, vanadium, and zirconium.

428. KELLEY, K. K. Contributions to the Data on Theoretical Metallurgy, IX. The Entropies of Inorganic Substances. Revision (1940) of Data and Methods of Calculation. Bureau of Mines Bull. 434, 1941, 115 pp.

The purpose of this bulletin is to give the available values of the entropies at 298.1° K. of the elements and inorganic compounds and an explanation of the methods employed in calculating entropies.

429. ___. Contributions to the Data on Theoretical Metallurgy, X. High-Temperature Heat-Content, Heat-Capacity, and Entropy Data for Inorganic Compounds. Bureau of Mines Bull. 476, 1949, 241 pp.

Correlates available high-temperature heat-content and specific heat data for inorganic substances and formulates tables and algebraic expressions for their representation.

430. ___. Specific Heat of Zirconium Dioxide at Low Temperatures. Ind. and Eng. Chem., vol. 36, April 1944, p. 377.

The specific heat of crystalline zirconium dioxide was measured throughout the temperature range 52° to 298° K., and the entropy computed as $S°_{298.16} = 12.03 \pm 0.08$. The entropy and free energy of formation from the elements are, respectively, $\Delta S°_{298.16} = -46.5$ and $\Delta F°_{298.16} = -244{,}200$.

KELLY, L. S. See abs. 297.

431. KEMPER, R. S., JR. Zirconium-Silver System. Oregon State Coll. (Thesis), June 1952, 60 pp.

The thesis deals with preparation of alloys of zirconium and silver and determination of the phase relationships resulting from a combination of these two metals.

432. KENDALL, J. Separations by the Ionic Migration Method. Science, vol. 67, No. 1728, Feb. 10, 1928, pp. 163-167.

Summary of work on the ionic-migration method for effecting difficult separations. Originally, investigations of this method were carried out between 1920 and 1926 and continued through 1928 at New York University.

KETCHAM, H. C. See abs. 721.

433. KEYS, D. A. Present and Future Applications of Atomic Energy to Industry. Ind. Canada, vol. 54, No. 3, July 1953, pp. 273-278.

A survey of present and potential uses of atomic energy and the materials, including zirconium, necessary for this expansion.

434. KIEFFER, R., AND HOTOP, W. (Comparative Properties of Sintered Versus Cast Metals and Alloys). Kolloid-Ztschr., vol. 104, No. 2-3, 1943, pp. 208-223.

Numerical data are given on physical and mechanical properties (in sintered-versus-cast and wrought state) of tungsten, molybdenum, tantalum, columbium, titanium, zirconium, thorium, vanadium, chromium, and uranium; copper, silver, gold, platinum, nickel, cobalt, pure iron, cast iron, steel; sintered alloys; tungsten carbide-cobalt system, examples; and iron-nickel-aluminum system, examples.

435. KIESS, C. C. Wave-Length Measurements in the Arc and Spark Spectra of Zirconium. Nat. Bureau of Standards Sci. Papers, vol. 22, No. 548, 1927, pp. 47-60.

The arc-and-spark spectra of zirconium as emitted between electrodes of pure zirconium metal were photographed with the concave grating and quartz prism spectrographs of the Bureau of Standards. The measured wave lengths in the arc spectrum cover the region from 4,881 A in the blue to 9,277 A in the infrared, thus extending present knowledge of the spectrum more than 2,000 units beyond the longest zirconium wave length heretofore observed. The arc spectrum in the regions investigated is superposed on a band spectrum in which the bands are shaded toward the red. The wavelength measurements of the spark spectrum extend from 2,163 A in the ultraviolet to 6,115 A in the red, and contain not only the lines of the singly ionized atoms but also those of doubly and trebly ionized atoms.

See also abs. 544.

436. KIESS, C. C., AND KIESS, H. K. Structure of the Arc Spectrum of Zirconium. Nat. Bureau of Standards Jour. Res., vol. 6, 1931, pp. 621-672.

Nearly 1,600 lines have been measured in the arc spectrum of zirconium between 2,085 A in the ultraviolet and 9,300 A in the infrared. Approximately 80 percent of these lines, which includes all but 7 for which temperature classes have been determined, has been classified as combinations between terms of the singlet, triplet, and quintet systems. The terms, without exception, are those required by Hund's theory, and many have been confirmed by Zeeman effect observations. Many pairs of terms of nearly the same value with the same inner-quantum number and arising from the same electron configuration mutually perturb one another, with the result that lines originating in them exhibit abnormal intensities and Zeeman effects. Both the lowest term of the spectrum, $\alpha\,{}^3F$, and the lowest term of the quintet system, $\alpha\,{}^5F$, form Rydberg series with higher terms, from which the distance separating the ground states of zirconium I and zirconium II proves to be 56,077 $cm^{-1}$, giving an ionization potential of 6.92 volts for the neutral zirconium atom. The resonance lines are given by the combination $\alpha\,{}^3F - z^5G^{\circ}$, whereas the raies ultimes are given by $\alpha\,{}^3F - z^3G^{\circ}$. More than 200 zirconium lines have been identified with dark lines in the solar spectrum, of which nearly half represent term combinations that do not appear in emission spectra observed in the laboratory.

437. ___. Structure of the Spectrum of Singly Ionized Zirconium. Nat. Bureau of Standards Jour. Res., vol. 5, 1930, pp. 1205-1241.

Seventy-five percent of the lines observed in the spark spectrum of zirconium have been classified as combinations between terms of the quartet and doublet systems of zirconium II. The terms that have been found are in all cases those required theoretically for an atom with three outer electrons. All the terms, except one, that can possibly arise from configurations of the electrons when they occupy 4d, 5s, and 5p orbits have been found. Of the terms possible, when one of the electrons removes to a 5d or 6s orbit only a few have been found, of which some form Rydberg series with the low terms. In all, 10 pairs of series-forming terms have been detected with either ${}^3F$, ${}^1G$, or ${}^1D$ of zirconium III as limit. The results given by these different series for the distance between $a^4F_1 1/2$, the lowest term of zirconium II, and $a^3F_2$, the lowest term of zirconium III, are very consistent, the mean value being

$113{,}175 \text{ cm}^{-1}$, corresponding to an ionization potential of 13.97 volts for the ion zirconium$^{+}$. The irregular doublet law shows a close parallelism between the term structures of the neutral Yt atom and the singly ionized zirconium atom. The list of zirconium II lines appearing in the sun is extended and includes lines that have not been observed in laboratory sources but may be calculated from permissible combinations.

438. KIESS, C. C., AND LANG, R. J. Structure of the Spectra of Doubly and Trebly Ionized Zirconium. Nat. Bureau of Standards Jour. Res., vol. 5, 1930, pp. 305-324.

The spectra emitted by zirconium atoms that are doubly and trebly ionized have been observed with the grating and prism spectrographs of the National Bureau of Standards and with the vacuum-grating spectrograph of the University of Alberta. These spectra have been analyzed and the series relationships involved in them have been established. The terms that have been found to explain the spectra are, without exception, those required by the quantum theory. Zirconium IV is a doublet spectrum, which results from the migration of a single electron; in its unexcited state it occupies a $4_3$ orbit. From a series of S terms, an ionization potential of $33.83\nu$ is derived, corresponding to a value of $274{,}067 \text{ cm}^{-1}$ for the lowest term $4^2D_{\frac{3}{2}}$. Zirconium III consists of singlet and triplet systems, the terms of which result from the interaction of two electrons occupying $4_3$ orbits in their unexcited state. Sequences of $^1D$ and $^3D$ terms have been found, which result when one of the electrons occupies an $\eta_1$ orbit and the other remains in a $4_3$ orbit. These term sequences place the ground term, $^3F_2$, at $194{,}441 \text{ cm}^{-1}$, which gives $24.00\nu$ as the ionization potential of zirconium$^{++}$. Among the zirconium III multiplets are those representing the transition $4f \rightarrow 4d$. These multiplets and also those representing intersystem combinations exhibit anomalous intensities.

KIESS, H. K. See abs. 436, 437.

439. KIESSLING, R. Borides of Some Transition Elements. Acta Chem. Scand., vol. 4, 1950, pp. 209-227.

A comprehensive discussion of the structural work on the borides of the transition elements, including tables of axial lengths and interatomic distances. Discusses structures with respect to the arrangement of the boron atoms.

KIHLGREN, T. E. See abs. 233.

KILEEN, P. L. See abs. 809.

440. KING, A. S. Electric-Furnace Spectrum of Hafnium. Astrophys. Jour., vol. 70, 1929, pp. 105-113.

The spectrum of metallic hafnium has been examined from λ2,640 to λ6,500 in the carbon-tube furnace and compared with the spectra of the arc and spark. A list of 338 lines includes the stronger neutral and ionized lines in this range. The usual temperature classification is given for the lines of the neutral spectrum, based on their relative intensities at 2,900° and 2,600° C. The lines which, judged by their relative intensities in arc and spark, belong to the ionized atom are absent from the furnace spectrum. The ionized lines are selected on the basis of their behavior in the three sources. Attention is called to a band spectrum appearing in the arc in air and presumably due to the oxide. Wavelengths are given for the first head in each of 9 groups between λ3,200 and λ5,700.

441. KING, A. S., AND CARTER, E. Electric-Furnace Spectra of Yttrium, Zirconium and Lanthanum. Astrophys. Jour., vol. 65, 1927, pp. 86-107.

Concerns the furnace spectra of yttrium λ2,808- λ7,882, zirconium λ2,792- λ 8,305, and lanthanum λ2,709- λ8,347. Temperature stages from 2,000° to 2,800° C. were employed to observe the initial appearance of lines and their rate of increase in intensity, supplemented by low-temperature absorption spectra in the ultraviolet. A direct comparison with arc-and-spark spectra showed the changes undergone in these sources and served to select the enhanced lines. The numbers of lines classified are 451 of yttrium, 858 of zirconium, and 695 of lanthanum. Many enhanced lines of yttrium and lanthanum and some of zirconium are emitted by the furnace, their intensities in furnace and arc indicating the relative energy levels of the ionized atom. For zirconium, a temperature of about 2,400° was required before any considerable number of lines appeared, and for this element a large proportion of lines emitted by the arc are enhanced lines. In the lanthanum spectrum a large number of close doublets is noted and some triplets, all of which have been previously listed as single lines; also the large proportion of lines relatively stronger in the furnace than in the arc.

KING, B. W. See abs. 740.

442. KINGERY, W. D. Metal-Ceramic Interactions: IV. Absolute Measurement of Metal-Ceramic Interfacial Energy and the Interfacial Adsorption of Silicon From Iron-Silicon Alloys. Jour. Am. Ceram. Soc., vol. 37, No. 2, Feb. 1, 1954, pp. 42-45.

The surface and interfacial energies in the system Ni-$Al_2O_3$ and Ni-$ZrO_2$ were determined at elevated temperatures by means of equilibrium interfacial angle measurements. Coincidental measurements of surface tension and contact angle for iron and iron-silicon alloys in $Al_2O_3$ give values of interfacial energy. Application of Gibbs' isotherm indicates that interfacial adsorption of silicon takes place in this system.

___. See abs. 600, 601.

443. KINGERY, W. D., ECONOMOS, G., HUMENIK, M., JR., AND BERG, M. Development of Metal-Ceramic Compositions Suitable for Service at Elevated Temperatures. 8th informal Monthly Rept. Massachusetts Inst. Technol., NEPA-1391, MIT-54, March 1950, 10 pp.

Reviews literature for ceramic-metal reactions and reports preliminary results of tests with nickel and silicon on alumina and stabilized zirconia.

KINGSWOOD, V. S. See abs. 586.

444. KIRBY, D. Pure Oxide Refractories. Metallurgia, vol. 30, No. 176, June 1944, pp. 65-69.

Appreciable developments have taken place in the commercial production of pure oxide refractories in this country in recent years, especially in the attainment of high degrees of purity, very thin-walled shapes and improved finish. Apart from alumina ware, the bulk of the oxide ware came from Germany before the war, and the demand for increased supplies has led to considerable progress in manufacturing technique. Various kinds of pure oxide refractories and particulars of their applications and properties are discussed.

445. ___. Pure Oxide Refractories. Refractories Jour., vol. 27, No. 1, January 1951, pp. 11-14.

Much research and development have been done on pure oxide refractories, including zirconium, which can be used at high commercial temperatures. Physical properties, applications, chemistry, etc., of pure oxides are covered.

KITCHENER, J. A. See abs. 453.

446. KITCHIN, E. S., AND WINTERSON, W. G. Malacone, a Silicate of Zirconium, Containing Argon and Helium. Jour. Chem. Soc. (London), vol. 89, 1907, pp. 1568-1575.

Discusses the chemistry of malacone, a silicate of zirconium.

447. KLEINT, R. E. System of Zirconium-Tantalum Alloys - Zirconium Rich Portion. Oregon State Coll. (Thesis), August 1949, 61 pp.

A report of the preliminary investigation of the zirconium-rich portion of the zirconium-tantalum system. There is a phase change in the region of 790° C. in all alloys up to at least 16 percent tantalum. The transformation taking place at 790° C. is thought to be eutectoid temperature, and the eutectoid lies between 10 and 15 percent tantalum. A second transformation takes place on heating at 910° C. The solubility of tantalum in zirconium is above 30 percent at 1,100° C. and at 950° C. and 30 percent tantalum hetrogenious field exists. At 950° C., the solubility extends to at least 10 percent tantalum, and at room temperature the solubility of tantalum in zirconium is less than 1 percent. The solubility of tantalum in alpha zirconium increases with temperature. Experimental procedures followed are described in detail.

448. KLINGENBERG, J. J., VLANNES, P. N., AND MENDEL, M. G. Benzilic Acid as a Reagent in Gravimetric Determination of Zirconium. Anal. Chem., vol. 26, No. 4, April 1954, pp. 754-756.

Benzilic acid can be used as a reagent for the gravimetric determination of zirconium and will precipitate zirconium quantitatively with increasing acidity if the quantity of benzilic acid used is also increased. The zirconium benzilate precipitate filters, washes, and ignites readily; and the voluminous nature of the precipitate is advantageous in detection and determination of small quantities of the element, although direct weighing is not possible. Benzilic acid also acts selectively in the presence of many of the foreign ions normally appearing with zirconium and can be utilized in the determination of zirconium in steel alloys.

449. KNECHT, W. New Design of Metal to Ceramic Seals Compared With Former Designs. Wright-Patterson Air Force Base, AF-TR-6101, February 1950, 19 pp.

Historical survey of former designs of metal to ceramic seals. On the basis of these techniques, the advantages of a new design are described. By application of the powder-press technique, the bond is formed by pressing together the powders of metal and ceramic. This process forms close contact between the powders and greatly increases the area of the bond. Microphotographs of metallized steatites, which prove an interaction between the molecules of metal and ceramic, are included in the report. It is concluded that many difficulties of related-seal techniques, such as those connected to the brazing process and to the matching of the thermal expansion, are eliminated by the new method.

KNIGHT, J. D. See abs. 130, 335.

KNOLL, M. See abs. 242.

KNOWLES, H. B. See abs. 500.

KONDIAH, K. See abs. 649.

450. KOSTYLEVA, E. E. Metamictic Disintergration of the Zircon Group of Minerals. Geol. Survey, TEI-369, January 1954, 16 pp.; ch. in Voprosy mineralogii geokhimii i petrografii, U. S. S. R. Acad. Sci., Moscow, 1946, pp. 27-35.

This report is concerned with metamictic disintergration, especially its original interpretations of the role of water in crystal structure.

451. KRAUS, K. A., AND MOORE, G. E. Anion Exchange Studies, I. Separation of Zirconium and Niobium in HCl-HF Mixture. Oak Ridge Nat. Lab., ORNL-661, May 25, 1950, 14 pp.; Jour. Am. Chem. Soc., vol. 73, 1951, pp. 9-13.

The behavior of $Zr^{+4}$ and $Nb^{+4}$ on the anion-exchange resin Dowex -1 was studied in a number of HF-HCl mixtures. Separation of the two elements is excellent under various conditions. Zirconium is generally eluted first, but reverse-order elution can occur under certain conditions. In evaluating data attempts were made to interpret in terms of ionic species and their equilibria. (TID-3010)

452. KRAUS, K. A., AND MOORE, G. E. Anion Exchange Studies, III. Protactinium in Some HCl-HF Mixtures: Separation of Niobium, Tantalum and Protactinium. Jour. Am. Chem. Soc., vol. 73, June 1951, pp. 2900-2902.

The anion-exchange behavior of protactinium in HCl-HF mixtures has been studied and a number of conditions were found under which this element can be absorbed. Since its adsorbability differs widely from that of niobium and tantalum, excellent separation of this triad can be achieved under a variety of conditions.

453. KRESSMAN, T. R. E., AND KITCHENER, J. A. Cation Exchange With a Synthetic Phenolsulfonate Resin, Part II. Equilibria With Multivalent Cations. Jour. Chem. Soc., 1949, pp. 1201-1208.

The study described in Part I has been extended to equilibria between an ammonium resin and salts of beryllium$^{++}$, magnesium$^{++}$, calcium$^{++}$, strontium$^{++}$, barium$^{++}$, cadmium$^{++}$, copper$^{++}$, zinc$^{++}$, cobalt$^{++}$, nickel$^{++}$, lead$^{++}$, mercury$^{++}$, aluminum$^{+++}$, thorium$^{++++}$, and zirconium$^{++++}$. They obey the law of mass action, concentrations being used instead of activities. This is discussed in relation to activity coefficients in univalent-bivalent salt mixtures. All the sulfonate groups in the resin can be neutralized by an equivalent number of multivalent cations, and this leads to the hypothesis that multivalent ions are not closely associated with their valency number of sulfonate groups. Ionic size measured by the alpha° parameter seems to be a factor determining the affinity of bivalent cations for the resin. These observations can be reconciled by the assumption that the cation is close to one sulfonate group and relatively far from the other. The generally increasing affinity observed with increasing valency is in keeping with this concept. Incomplete dissociation of the salts of multivalent ions in solution is an important factor in determining the extent of salts of multivalent ions in solution and the extent of exchange with these ions; it also explains the effect of the anion.

454. KRIESSMAN, C. J. Magnetic Susceptibility of the Transition Elements. Phys. Rev., vol. 94, No. 4, May 15, 1954, pp. 837-844.

Reviews available data on the temperature dependence of the paramagnetic susceptibility of the transition elements. A theoretical treatment according to the band theory of solids is developed explicitly by means of a simple approximation to the Fermi function. Each term in the resulting theoretical formula may be directly and graphically interpreted in terms of the geometry of the density-of-states curve, allowing a simple and intuitive analysis of the susceptibility variation at any temperature. The empirical data on the temperature coefficient of susceptibility, on the absolute magnitude of the susceptibility, and on the specific heats of the transition elements are analyzed to suggest probable alterations in the available theoretical density-of-states curves.

455. KRISHNAMURTI, P. Use of Zirconium Tetrachloride in Organic Synthesis. Jour. Madras Univ., 1928, pp. 40-43.

Numerous efforts have been made from time to time to utilize the various anhydrous chlorides in the place of $AlCl_3$ in the Friedel-Crafts reaction but with partial success. Anhydrous ferric chloride has been proposed as a substitute especially in the preparation of ketones. Anhydrous $SnCl_4$, $SbCl_5$, $BCl_3$, and $TiCl_4$ have also been tried in some Friedel-Crafts reactions. This report deals with the use of anhydrous zirconium tetrachloride in some of the above reactions, and the results show that $ZrCl_4$ resembles $AlCl_3$ to a great extent in its salient physical and chemical properties.

456. KROGER, F. A. Classification of Known Luminescent Effects. Ch. on Some Aspects of the Luminescence of Solids. Elsevier Pub. Co., Inc., New York, N. Y., 1948, pp. 49-54, 287, 288.

It is possible to distinguish between transfer processes and characteristic processes in luminescent phenomena. This report discusses the classification of the known luminescent effects according to this distinction.

457. KROLL, W. J. Anhydrous Fluorides in Metallurgy. Metal Ind., vol. 83, No. 5, July 31, 1953, pp. 81-82; vol. 83, No. 6, Aug. 7, 1953, pp. 101-104; vol. 83, No. 7, Aug. 14, 1953, pp. 124-126, vol. 83, No. 8, Aug. 21, 1953, pp. 141-143.

A parallel has been drawn between the use of chlorides and fluorides in pyrometallurgy. The availability and prices of both are compared, and it is found that chlorides possess the advantages. The displacement of oxygen, sulfur, and other halogens by elementary fluorine proceeds one way only, with formation of fluoride. Consequently, all fluorides are stable when heated in dry oxygen or dry air, which is an advantage over chlorides. They are, however, decomposed when heated in presence of water vapor, with evolution of HF. In this regard they behave like chlorides. This behavior is also the main cause of the damage to agriculture by fluorides escaping from aluminum cells. Oxide, sulfide, and halogen exchanges are possible with fluorides, and this offers possibilities for their production if aqueous methods are not successful. Assisted oxide/fluoride exchanges are described, especially the Copaux process of beryllium and zirconium double-fluoride production from beryl and zircon ores. Fluoridizing roasting is shown in a few examples in which $SO_3$ acts as a reagent. Reduction of fluorides by other elements such as hydrogen, sodium, calcium, aluminum, and magnesium, and by alloys, as, for instance, $CaC_2$ and MgPb, is discussed as applied to the winning of metals such as uranium, beryllium, cerium, zirconium, and titanium, and their alloys. The use of bombs for fluoride reductions is submitted to scrutiny. Metal plating, alloy-powder production, and separation of alloy constituents by the use of fluorides are stressed. The fusion electrolysis of fluorides is discussed, and the fact that this type of electrolysis is based on oxide addition to the bath, and consequent consumption of anode carbon, is emphasized. The fusion electrolysis of aluminum is examined from the angle of fluorine chemistry, which leads to a study of the causes of fluorine losses. Reference is made to the means for condensing and precipitating these fluorides. The production of beryllium, magnesium, cerium, tantalum, boron, chromium, zinc, uranium, and thorium by fusion electrolysis is described. The use of soluble anodes and the possibility of alloy separation by fluoride electrolysis are considered.

458. ___. Production of Metal Powders by Fusion Electrolysis. (Ch. in Plansee Proc. edited by F. Benesovsky.) Metallwerk Plansee Ges, M. B. H. Reutte/Tyrol, 1952, pp. 160-170.

It has been shown that metal powders can be produced by fusion electrolysis at temperatures at which the cathode deposit appears in form of small crystals. The method may be one of metal-powder winning, in which insoluble graphite anodes are used, or of metal purification, where, starting from an impure compact metal anode, a powder of higher purity is obtained. These two kinds of electrolysis also permit making alloy powders. The crystals obtained have special properties not usually found in powders made by other methods, especially highest purity, rough grain if wanted, and metallic condition from the core to the surface. The fusion electrolysis with solid deposit can be applied to zirconium.

459. ___. Rare Metals as Constituents in Light Alloys. Light Metal Age, vol. 3, December 1945, pp. 23-30.

Outlines the effects of additions of rare metals to aluminum and magnesium alloys and suggests the value and direction of further experiments with such additions. Factors affecting the availability of rare metals, such as occurrence of the ores, market demands, and methods of extraction, are considered. Methods of introducing the rare metals into light alloys are described.

460. KROLL, W. J. Rare Metals of the Earth. South African Min. and Eng. Jour., vol. 57, July 27, 1946, pp. 541-543.

Reviews properties, uses, potentials, and current research status of lithium, boron, gallium, indium, titanium, germanium, uranium, and zirconium. Emphasis has been placed on the need for more research on the methods of separation from closely related elements, of extraction from the ores, preparation of the elements in the degree of highest purity, making master alloys, and studying all physical and chemical properties of the metals and their alloys.

See also abs. 18.

461. KROLL, W. J., AND SCHLECHTEN, A. W. Reactions of Carbon and Metal Oxides in a Vacuum. Jour. Electrochem. Soc., vol. 93, No. 6, 1948, pp. 247-258.

Reviews literature on the reactions of carbon and metal oxides in a vacuum and discusses the results of an experimental study of the reduction of several metal oxides by carbon in a vacuum. None of the refractory oxides studied were stable in contact with carbon in a vacuum at temperatures above 1,380° C. Oxides of multivalent metals reacted at temperatures of 700° C. or less. As a method for producing pure metals, best results were obtained with chromium, vanadium, columbium, and tantalum. A chromium metal analyzing 97 percent chromium and a vanadium metal analyzing 93 percent vanadium were obtained. It is concluded that the vacuum reduction method would be practical only for the production of the more expensive and rare metals.

462. ___. Titanium and Zirconium - Two Metals of the Future. Metal Ind. (London), vol. 69, Oct. 18, 1946, pp. 319-322.

This report gives methods for extracting titanium and zirconium.

463. KROLL, W. J., SCHLECHTEN, A. W., CARMODY, W. R., YERKES, L. A., HOLMES, H. P., AND GILBERT, H. L. Recent Progress in the Metallurgy of Malleable Zirconium. Trans. Electrochem. Soc., vol. 92, 1947, pp. 99-113.

Describes improved methods in the various operations for the production of ductile zirconium from zircon sands - essentially improved methods of producing zirconium carbide from zircon sand by using an arc furnace and melting zirconium metal in graphite crucibles. The slight carbon contamination apparently does not appreciably impair the working properties of the metal. Other improvements are refinements of the process as described in an earlier publication.

464. KROLL, W. J., AND STEPHENS, W. W. Production of Malleable Zirconium. Ind. Eng. Chem., vol. 42, No. 2, February 1950, pp. 395-398.

Describes a pilot plant for the production of 300 pounds of zirconium sponge a week, which was in operation at the U. S. Bureau of Mines station in Albany, Oreg. A flowsheet of the process, a layout plan of the plant, and a list of the vacuum pumps and transformers are presented to explain functioning of the equipment.

465. KROLL, W. J., STEPHENS, W. W., AND HOLMES, H. P. Production of Malleable Zirconium on a Pilot-Plant Scale. Jour. Metals, vol. 188, December 1950, pp. 1445-1453.

Describes a pilot plant producing 600 pounds of zirconium sponge a week. It comprises an arc furnace to make zirconium carbide, a chlorinator producing a raw chloride, a purification vessel to eliminate zirconium oxide and iron from this chloride, 2 reduction vessels, 2 vacuum retorts for salt separation, and a graphite-resistor vacuum furnace to melt ingots. A layout of the plant, power consumption, operation schedules, and production costs are given.

466. Kroll, W. J., STEPHENS, W. W., AND WALSTED, J. P. Graphite-Rod Hairpin-Resistor Radiation Furnace for High Temperatures. Jour. Metals, vol.188, November 1950, pp. 1394-1395.

The hairpin graphite-resistor radiation furnace is well adapted for producing zirconium carbide from oxide at temperatures between 1,800° and 2,000° C. with 100 percent recovery of the zirconium content. The power consumption in a rather small furnace is only about 5.7 kw.-hr. per pound of carbide produced. The voltage variation during the run is slight, so that cheap transformers can be used to supply the energy. The carbide obtained is of very good quality as far as its ammenability to chlorination is concerned. The furnace described may be well adapted for producing other high-melting carbides or borides, such as titanium carbide or boride. It cannot be recommended for reducing oxides that develop large quantities of $CO_2$, since this gas consumes the electrode at a rapid rate.

KUCHERENKO, O. A. See abs. 74.

467. KÜRTI, N., AND SIMON, F. Experiments at Very Low Temperatures Obtained by the Magnetic Method, II. New Supraconductors. Proc.Roy. Soc. (London), Series A, vol. 151, 1935, pp. 610-623.

Discusses the question of cooling additional substances with the paramagnetic salt by applying the magnetic method. The simplest way - pressing the two substances into a pill - was used in the present investigation. It is shown how the measurement of the magnetic behavior of a metal can be used for the detection of supraconductivity and for finding the transition point and the threshold values. Three new supraconductors were found in the new temperature region, namely, cadmium, zirconium, and hafnium, the normal transition points being respectively 0.54°, 0.70°, and 0.35°. The samples of gold, copper, bismuth, magnesium, and germanium did not become supraconductive down to 0.05°.

KULIN, P. A. See abs. 511.

468. KUNDU, D. N., AND POOL, M. L. Columbium$^{96}$. Phys. Rev., vol. 75, No. 11, June 1949, pp. 1690-1692.

Columbium$^{96}$ has a half life of 23.35 hours. It decays with the emission of negative beta-particles of maximum energy 0.67-Mev. and 1.03-Mev. gamma rays. No X-rays are emitted. The assignment is made by using enriched isotopes of zirconium.

KURA, J. G. See abs. 365.

KURBATOV, J. D. See abs. 469.

469. KURBATOV, M. H., WEBSTER, H. B., AND KURBATOV, J. D. Some Properties of Thorium in Very Dilute Aqueous Solutions. Jour. Phys. and Colloid Chem., vol. 54, 1950, pp. 1239-1250.

Coagulation of thorium from $10^{-4}$M solution at different pH values and variable concentrations of foreign ions is similar to the removal by filtration of invisible quantities of UX in concentrations of $10^{-13}$ M. At constant time intervals with carbonate content minimized, an increase in $OH^-$ increases the removal of UX present in trace amounts. The plot of pH versus fraction of UX removed from solution gives an experimentally straight line between pH 1.0 and 4.5. This is consistent with similar results on solutions containing $10^{-6}$ gram-atom of thorium and on the formation of radiocolloids of yttrium and zirconium.

470. KUZNETZOV, V. I. Color Reaction Tests for Zinc, Cadmium, Mercury and Other Elements. Compt. rend. acad. sci., U. R. S. S., vol. 41, No. 3, 1943, pp. 109-113.

Precipitation of zirconium under the influence of phenyl or alpha-naphthyl arsonic acid in the presence of a rhodanide-containing acidulated solution of methyl-violet (bluish-green in color) results in the appearance of a blue or violet color; 2 ml. of the investigated solution, 1 drop of HCl (sp. w. 1.12), 1 drop of 0.06 percent methyl-violet, 2 drops of 20-percent $NH_4CNS$ and 2 or 3 drops of a saturated solution of arsonic acid. Limiting dilution for zirconium, 1:>1,000,000. The detection of zirconium is possible in the presence of thorium in the proportions zirconium:thorium = 1:> 100 and with many other elements.

## L

**LAIT, J. R.** See abs. 610.

471. **LAMBERTSON, W. A., AND MUELLER, M. H.** Uranium Oxide Phase Equilibrium Systems: III, $UO_2$-$ZrO_2$. Jour. Am. Ceram. Soc., vol. 36, No. 11, November 1953, pp. 365-368.

The $UO_2$-$ZrO_2$-phase equilibrium system contained no new compounds but was found to contain extensive solid solution. The $UO_2$ solid solution was cubic and extended up to 52 mole-percent $ZrO_2$. Its lattice parameter varied from 5.46 to 5.32 a.u., with an increasing percentage of $ZrO_2$. The zirconia solid solution, when examined by quenching techniques, was tetragonal and extended from 53 to 100 percent $ZrO_2$. There were some indications that $ZrO_2$ transformed to a polymorphic form other than monoclinic or tetragonal at approximately 1,900° C.

472. **LAND, L. C.** Study of Ceramic Liners for Uncooled Rocket Motor Chambers. Jet Propulsion Lab., California Inst. Technol., NP-1752, Oct. 1, 1948, 45 pp.

$ZrO_2$, $ZrSiO_4$, SiC, and BeO were tested as liners in a $H_2O$-cooled, liquid-propellant, 750-pound-thrust rocket motor. For overall performance, stabilized $ZrO_2$ was the best liner tested. It is concluded that ceramic liners for the chambers of uncooled rocket motors of short duration (<220 sec.) are feasible with liquid propellants that develop chamber temperatures of ~ 5,000° F. (TID-3010)

**LANE, I. R., JR.** See abs. 298.

**LANG, R. J.** See abs. 438.

**LAPIN, V. V.** See abs. 75.

473. **LARSEN, E. M., TERRY, G., AND LEDDY, J.** Preparation and Properties of Zirconium and Hafnium Chelates of Certain Beta-Diketones. Jour. Am. Chem. Soc., vol. 75, No. 20, Oct. 20, 1953, pp. 5107-5111.

Compounds of zirconium and hafnium with the composition $MK_4$ have been prepared with the following diketones: Acetylacetone, trifluoroacetylacetone, 2-furoylacetone, 2-fuoroyltrifluoroacetone, 2-thenoylacetone, 2-thenoyltrifluoroacetone, and 2-pyrroyltrifluoroacetone. The densities of the chelate compounds were determined by the standard pycnometric method, using water or petroleum ether saturated with the chelate as the immersion liquid. The molecular volumes calculated, in all cases, were greater for the hafnium compound than the zirconium compound, except for acetylacetone and 2-pyrroyltrifluoroacetone derivatives where the molecular volumes were almost identical. The ultraviolet absorption spectra for the nonfluorine-containing chelate compounds in cyclohexane are similar to the parent diketones. For the metal derivatives of the fluorinated diketones, the $lambda_{max.}$ associated with the enol ring is shifted to longer wave lengths, as compared to the $lambda_{max.}$ of the free diketone. The $lambda_{max.}$ for the zirconium chelates shifted to slightly longer wave lengths than for the corresponding hafnium compound.

474. **LARSEN, E. M., AND WANG, P.** Ion Exchange of Zirconium and Hafnium in Perchloric Acid With Amberlite IR-120. Univ. Wisconsin Tech. Rept. VI, NP-5289, Aug. 5, 1954, 23 pp.

Batch experiments with zirconium-hafnium perchlorate solutions and Amberlite IR-120 were made over total metal-ion concentrations of $1 \times 10^{-2}$ to $1 \times 10^{-6}$ molar, and at 2 M, 1 M, and 0.5 M perchloric acid at constant ionic strength of 2. The data show that the metal ions are hydrolyzed in the resin phase. The data can be interpreted in terms of unhydrolyzed metal species $M^{+4}$ in the aqueous phase at 1 and 2 M hydrogen ion. The distribution data show that zirconium is favored over hafnium in the resin phase, with the ratio of the distribution coefficients, $D_{Zr}/D_{Hf}$, increasing in favor of zirconium at the lower aqueous hydrogen-ion concentration. At high total metal-ion concentration, the hafnium appears to enter into mixed zirconium-hafnium polymers at hafnium concentrations considerably below that at which the hafnium-polymer formation alone would be significant.

475. **LARSEN, E. S., JR., WARING, C. L. AND BERMAN, J.** Zoned Zircon From Oklahoma. Am. Mineral., vol. 38, No. 11-12, November-December 1953, pp. 1118-1125.

Large zircon crystals from a pegmatite body in the Wichita Mountains, Okla., are zoned with fresh and metamict zircon. The metamict zircon is chiefly isotropic $\eta = 1.82$; same is uniaxial positive, $\omega = 1.85$, $\epsilon = 1.86$. The change from fresh to metamict zircon seems to be an abrupt and not a gradual one. The age of the zircon is determined at 635 million years from alpha determinations and 641 million years from chemical determinations of uranium and thorium.

476. **LASDAY, A. H.** Total Neutron Cross-Sections of Several Nuclei at 14 Mev. Carnegie Inst. Technol., NP-1845, Sept. 10, 1950, 89 pp.

Several total neutron cross-sections were obtained from a good geometry transmission measurement, using neutrons produced by bombardment of a beryllium target by 15 Mev. cyclotron-produced deuterons. Neutrons in the energy range of 13 to 15 Mev. (13.9 Mev. mean energy) were detected by allowing the neutron beam to impinge on a polyethylene radiator and then detecting recoil protons by passing them through a proportional counter telescope. With a small correction for elastic scattering included, the following total neutron cross sections in barns were obtained: Hydrogen, 0.77 ± 0.04 (from polyethylene and carbon cross sections); beryllium, 1.41 ± 0.11; carbon, 1.24 ± 0.06; titanium, 2.24 ± 0.29; vanadium, 2.52 ± 0.24; zirconium, 2.37 ± 0.35; and lead, 4.97 ± 0.27. The zirconium and lead values are anomalously small, indicating the effect of closed-shell structure of the nuclei $_{40}Zr^{90}$ (48 percent abundant isotope) and $_{82}Pb^{208}$ (52 percent abundant isotope).

**LAWRENCE, K. R.** See abs. 368.

**LAWRENCE, W. G.** See abs. 270, 271.

**LeBLANC, J. M.** See abs. 162.

**LEDDY, J.** See abs. 473.

**LEE, H. T.** See abs. 105, 106, 107, 108.

477. **LEONTIS, T. E.** Room and Elevated Temperature Properties of Some Sand Cast Magnesium-Base Alloys Containing Zinc. Trans. AIME, vol. 15, No. 4, Tech. Pub. No. 2371, June 1948, 35 pp.

The effects of the following elements added to magnesium-zinc alloys either separately or in combinations, have been investigated: Aluminum, cadmium, calcium, cerium, tin, silver, thallium, and zirconium. The results show that the addition of either zirconium or manganese produces alloys having the best combination of tensile properties at room and elevated temperatures and creep resistance at elevated temperatures. Whereas magnesium-zinc alloys containing either cerium or calcium exhibit marked temperature resistance as manifested by relatively little change in strength with increasing temperature, the level of the strength properties of these alloys is very low compared with the magnesium-zinc-zirconium alloys.

**LESLIE, H. L. C.** See abs. 840.

478. **LESSING. L. P.** Pure Metals. Sci. Am. vol. 191, No. 1, July 1954, pp. 36-40.

Summarizes the exploration and development of pure metals and their future potentials; also mentions various private and government laboratories doing important research in this field.

LEVESQUE, P. See abs. 221, 235, 236.

LEVI, H. See abs. 354.

LEWEY, F. H. See abs. 62.

479. LEWIS, W. S. Minerals of the Future. Hobbies, vol. 54, December 1949, pp. 151-152.

Reviews the development and expansion of several metals and minerals, including zirconium and zircon.

LIDMAN, W. G. See abs. 333.

480. LIGHT METAL AGE. Zirconium - How it is Fabricated. August 1954, pp. 16-17, 32, 37.

Outlines all phases in fabricating zirconium-forging, rolling, welding, brazing, soldering, joining, grinding, machining, extrusion and deep drawing, tube and rod fabrication, wire drawing, annealing, cleaning, finishing, and electroplating.

481. LIGHT METALS. Advances in Magnesium Technology. Vol. 12, January 1949, pp. 24-28.

Summarizes the most recent developments in magnesium technology; compares alloys in which additions of zirconium, cerium, and beryllium are used.

482. ___. Magnesium - the Key to the Future. Vol. 12, December 1949, pp. 674-675.

Discusses briefly magnesium-zirconium alloys and their heat treatment.

483. ___. Zirconite Sand in Foundry Practice. Vol. 14, No. 154, January 1951, pp. 50-52.

A report on the use of zirconite sand, $ZrSiO_2$, in foundry practice for aluminum and magnesium castings and methods for such use.

LILLIENDAHL, W. C. See abs. 657, 835.

LILLY, R. C. See abs. 376.

484. LISTER, B. A. J., AND McDONALD, L. A. Some Aspects of the Solution Chemistry of Zirconium. Atomic Energy Res. Est., England, AERE C/R 801, 1951, 32 pp.

Deals with some aspects of the chemistry of zirconium in nitric, hydrochloric, perchloric, and sulfuric acid solutions. Reviews our present unsatisfactory state of knowledge of the species existing in such solutions. Ion-exchange techniques have been used to determine the ionic change of zirconium species and the degree of cation-anion interaction to form complex cations and to illustrate the presence of anionic complexes in solution. In addition, the rate of diffusion from solution into exchangers of different cross linking has given information on the ionic size at various acidities. Other experiments include measurement of the rate of self-diffusion in solution, electromigration studies, pH determinations, and measurement of titration curves.

485. LITTON, F. B. Zirconium Alloy Project, Report No. 2. Foote Mineral Co., ATI-97917, NP-3279, Aug. 10, 1948, 8 pp.

Pure zirconium metal has poor resistance to oxidation at 400° C. Oxide formed at the surface does not protect the metal from further attack. Even though all the data were not complete at this time, enough evidence was available to indicate that carbon has a deleterious effect on the oxidation resistance of zirconium. The extremely poor oxidation resistance of cast zirconium was attributed to the carbon pickup from the graphite crucible during melting.

Nickel up to 10 percent did not appreciably improve the physical or oxidation properties of zirconium because of the limited amount of zirconium-nickel intermetallic compound that was soluble in the primary alpha-phase. The hafnium content of $ZrO_2$ was reduced to 0.2 percent. Experimental work is continuing to improve the methods used for separation. A pilot plant was laid out and is being set up for producing 13-pound lots of $ZrO_2$ relatively free from hafnium. A study was made to determine zirconium-alloy possibilities with all the elements inthe periodic table (TID-3010).

486. LITTON, F. B. Zirconium Alloy Project, Report No. 3. Foote Mineral Co., ATI-97918, NP-3281, Sept. 16, 1948, 17 pp.

Discusses the physical properties of commercial zirconium wire. Monoclinic $ZrO_2$ initially forms when zirconium metal is heated in air. On prolonged heating, the monoclinic lattice changes to the tetragonal type. Neither oxide forms protective coatings. $O_2$ dissolved in the surface of zirconium forms a hard surface layer, which may suggest engineering usage. The method of surfacing graphite crucibles with tungsten metal prior to melting zirconium alloys, to reduce carbon contamination, did not prove effective. A thermodynamic study predicted that under certain conditions carbon content could be reduced by adding oxides to the melt. Tantalum and titanium have promise of satisfactorily alloying with zirconium, whereas tungsten, molybdenum, and chromium do not appear satisfactory for alloy additions. Tantalum and aluminum increased the heat resistance of zirconium. The metallographic study of the zirconium-aluminum alloy was not completed (TID-3010).

487. ___. Zirconium Alloy Project, Report No. 4. Foote Mineral Co., ATI-97917, NP-3277, Oct. 13, 1948, 14 pp.

Decarburization of zirconium melted in graphite by oxide addition was not feasible. Oxide additions did not reduce the carbon content. It was shown, however, that aluminum addition did reduce carbon crucible contamination. Aluminum addition greatly increased the heat resistance of cast zirconium. ~3.0 percent aluminum was soluble in zirconium, and aluminum appeared very promising as an alloying metal. It should be pointed out that a pure zirconium-aluminum alloy probably would be satisfactory for applications requiring good X-ray or neutron transmittal. Further experiments with zirconium-tantalum alloys showed that adherent oxides are formed when they are heated in air at 750° C. Zirconium-rich alloys containing niobium, vanadium, platinum, beryllium, and silicon were not as resistant to oxidation as either zirconium-aluminum or zirconium-tantalum alloys (TID-3010).

488. ___. Zirconium Alloy Project, Report No. 5. Foote Mineral Co., ATI-97920, NP-3301, Nov. 23, 1948, 15 pp.

The tensile strength, yield strength, and elongation of iodide zirconium containing 2.5 percent hafnium are reported. Aluminum-zirconium, tantalum-zirconium, and aluminum-tantalum-zirconium alloys were prepared; data on the workability and microstructure are given. Tensile strength, elongation, and yield strength of tantalum-zirconium alloys up to 12.5 percent tantalum are given. Some data are given on the separation of hafnium from zirkite or solution (TID-3010).

489. ___. Zirconium Alloy Project, Report No. 7. Foote Mineral Co., ATI-97922, Jan. 31, 1949, 10 pp.

Zirconium-aluminum alloys reduced more satisfactorily at 1,000° than at 900° C. At the higher temperature there was indication that alloying would occur between the iron sheath and the zirconium alloy. Because these alloys were held at 1,000° C. for a minimum of time in these experiments, this alloying effect was inconsequential. Further work was done on the heat treating of zirconium-tantalum and zirconium-titanium-aluminum alloys, which added to evidence previously presented that these systems were susceptible to an aging process. Work of a fundamental nature is needed to select the best compositions and heat-treating procedures for these systems. Crude zirconium sponge was obtained, and work was done to obtain iodide zirconium at the 0.8 hafnium-zirconium level. Insufficient zirconium metal was obtained for adequate measurements of properties. Chlorination of purified $ZrO_2$ was found to proceed 2.4 times faster than chlorination of zirkite ore. $ZRCl_4$ at 0.54 hafnium: zirconium ratio was produced during this period. Work was continued on the preparation of $ZrO_2$ at 0.1 hafnium:zirconium ratio and of relatively pure $HfO_2$. Operations of the hafnium concentration unit at Exton was started through treatment of 500 gallons of $ZrOSO_4$-$H_2SO_4$ solution (TID-3010).

490. LITTON, F. B. Zirconium Alloy Project, Report No. 8. Foote Mineral Co., ATI-97923, NP-3276, Mar. 4, 1949, 13 pp.

Reports spectrographic and chemical analyses of iodide zirconium. The effect of cold work on the tensile properties of zirconium was determined. Maximum properties were obtained after 40-percent reduction. The average maximum tensile and yield strengths were 75,000 and 60,000 p.s.i., respectively, with about 2-percent elongation. The tensile properties of graphite-melted zirconium-aluminum, heat-treated zirconium-tantalum, zirconium-niobium and zirconium-tantalum-niobium alloys were measured. The particular alloy giving the highest strength coupled with elongation was a 4-percent-aluminum, 96-percent-zirconium alloy. The tensile and yield strengths of the alloy were 122,000 and 113,000 p.s.i., respectively, and the elongation was 12 percent. Heat-treated zirconium-tantalum alloys were ~10,000 p.s.i. stronger than untreated specimens. Zirconium-niobium alloys were not as strong as zirconium-tantalum alloys. However, it was observed that 50 percent of the tantalum content could be replaced by niobium without seriously impairing the strength of the 17.5 percent tantalum-zirconium alloy. Preliminary work incidental to preparing and testing codeposited zirconium-aluminum alloys was completed. One such alloy, containing 2.6 percent aluminum, was cold swaged into filament wire. Vacuum arc-melted zirconium-aluminum alloys were observed to possess better workability than graphite-melted alloys of similar composition. The oxidation resistance of arc-melted zirconium was superior to graphite-melted zirconium. However, iodide zirconium had better oxidation resistance than hot-worked arc-melted material. There were indications that the oxidation resistance of zirconium depended not only on the contaminants introduced by melting but also on the relative amounts of alpha and beta phases present. The effect of increasing the aluminum content on workability of 50-50 titanium-zirconium graphite-melted alloy was investigated. Alloys containing 50 percent and more aluminum had poor workability (TID-3010).

491. ___. Zirconium Alloy Project, Report No. 9. Foote Mineral Co., ATI-97924, NP-3275, Mar. 29, 1949, 9 pp.

The tensile properties of arc-melted zirconium and two alloys were determined. Oxidation-resistance tests indicated that ~1 to 2 percent aluminum addition increased the activity at 750° C. in both zirconium-aluminum and titanium-zirconium-aluminum systems, which trend was reversed on aluminum addition of ~4 to 6 percent. These alloys were not suitable for use in air at 750° C. Arc-melted zirconium-aluminum and titanium-zirconium-aluminum alloys containing as much as 6 percent aluminum were hot workable at 825° C. For some unexplained reason, however, the sheets obtained were brittle after rolling. The oxidation resistance of iodide zirconium and arc-melted zirconium was not appreciably affected by heat treatment. The oxidation resistance of arc-melted zirconium alloys containing 5 percent molybdenum, tungsten, nickel, and tantalum was measured at 750° C. in air. Nickel was the only addition in the series that showed resistance comparable to cold-rolled iodide zirconium. Molybdenum accelerated activity more than either tantalum or tungsten. Crude zirconium was produced from sublimed $ZRCl_4$ at 3.5 and 0.7 percent hafnium:zirconium ratio. Work was continued on the preparation of a zirconium-hafnium alloy series and relatively pure hafnium metal (TID-3010).

492. LITTON, F. B. Zirconium Alloy Project, Report No. 10. Foote Mineral Co., ATI-97925, NP-3278, May 18, 1949, 8 pp.

Analytical data are shown on the preparation of zirconium-hafnium alloys at 4-percent-hafnium concentration levels. The oxidation resistance at 750° C. and mechanical properties of zirconium alloys containing from 2.88 to 0.165 percent hafnium are reported. In this zirconium range hafnium produced less effect on the properties of zirconium than impurities (such as aluminum, magnesium, and nickel) included in the metal during processing. A second phase in the alloys studied was not identified but presumed to result from the impurities present. This problem is to be studied further. Work on arc-melted zirconium alloys containing up to 10 percent molybdenum, tungsten, nickel, and tantalum was studied. The heat resistance of none of these alloys was superior to unmelted iodide zirconium. The most promising composition in regard to tensile properties was the 1 percent tungsten-zirconium (~2.5 percent hafnium) alloy. Its tensile properties were as follows: 82,000 p.s.i. yield strength, 110,200 p.s.i. ultimate strength, and 7.3 percent elongation. Exploratory arc-melted alloys were prepared containing copper, magnesium, beryllium, boron, silicon, vanadium, chromium, and manganese. Mechanical properties, heat resistance, and corrosion data will be determined later. The second lot of 500 gal. $ZrOSO_4$ solution was treated to yield 91.8 percent of its original hafnium content. Work was started on further hafnium enrichment of the precipitates obtained (TID-3010).

493. ___. Zirconium Alloy Project, Report No. 11. Foote Mineral Co., ATI-97926, NP-3285, July 26, 1949, 14 pp.

A metallographic and hardness study of zirconium containing additions of iron, silicon, magnesium, aluminum, copper, and nickel. It was observed that iron, silicon, copper, and nickel formed complex phases with zirconium; ~3 percent copper was soluble in beta zirconium. The presence of 2 percent copper increased the solubility of other impurity metals above the transformation range. The phase previously observed in iodide zirconium was attributed to the presence of iron and silicon. These two metals had little or no solubility in either alpha or beta zirconium. Nickel also formed a complex with zirconium, which appeared as a second phase at low alloy concentration. Work will continue on the effect of magnesium and aluminum. Tensile properties of arc-melted and cold-rolled iodide hafnium-zirconium and aluminum-hafnium-zirconium alloys are reported. The best combination of properties was obtained on two alloys that contained iron, silicon, titanium, magnesium, aluminum, copper, nickel, and hafnium in very small amounts. The properties were ~97,000 and 133,000 p.s.i. for yield and tensile strengths, respectively, and 7.6 percent elongation. Alloy 355, which was contaminated with nitrogen during arc melting, had the following properties: Yield strength, 117,100 p.s.i.; tensile strength, 150,900 p.s.i.; elongation, 1.5 percent. A variation in hafnium content of zirconium from 8.2 to 0.1 percent resulted in no appreciable change in the tensile properties of the hafnium-zirconium alloys. Further work is underway to substantiate this observation. Arc-melted ingot prepared from iodide zirconium made from $N_2$-reduced sponge was cold-rolled with one intermediate anneal from 0.345 to 0.026 inches. Similar ingots prepared from zirconium made from magnesium-reduced sponge were not cold-workable into sheet. The tensile and yield strengths after annealing for 1/2-hour at 1,700° F. were comparable to the results previously obtained on hot-worked ingots. The elongation, however, was considerably greater. The tensile properties of the cold-rolled material after 77.7 percent reduction were as follows: Yield strength, 83,500 p.s.i.; tensile strength, 105,400 p.s.i.; elongation, 5.0 percent. Preliminary corrosion data are reported on arc-melted zirconium alloys. In addition to a hafnium-zirconium series, alloys containing nickel, tungsten, molybdenum, and tantalum were tested in fuming $HNO_3$, 30 percent $H_2O_2$, 1.2N HCL, and 1.78 N $H_2SO_4$. All the alloys tested were satisfactory for commercial usage at room temperature. The 1.0 and 2.5 tantalum-zirconium alloys possessed the best resistance to fuming $HNO_3$. Zirconium did not accelerate the decomposition of 30 percent $H_2O_2$ to the extent observed with either titanium or aluminum (TID-3010).

494. LITTON, F. B. Zirconium Alloy Project, Report No. 1. Foote Mineral Co., ATI-92428, NP-3445, Jan. 11, 1950, 17 pp.

A metallographic study of tungsten-zirconium alloys indicated that the transformation temperature of zirconium was raised by tungsten addition. Tungsten solubility in zirconium was ~4 percent in both alpha and beta modifications, and the system is probably peritectoidal. Tungsten-zirconium alloys containing relatively small amounts of tungsten possessed reasonable workability associated with relative high strength. The best combination of properties resulted from tests on "as-rolled" material at 400° C. Further work is necessary before the optimum properties can be established, based on composition. Similar study of molybdenum-zirconium alloys indicated that this system was probably peritectoidal with wide solubility (~5.36 percent) of molybdenum near the transformation temperature. Like the tungsten-zirconium alloys, molybdenum-zirconium alloys possessed reasonable workability associated with relatively high strength. More work is contemplated to determine properties versus composition in this system. It was observed that the rate of oxidation of iodide zirconium in still air was related to the past thermal history and to the aluminum content. The oxidation rate rises abruptly at ~0.15 percent aluminum. A new experimental iodide deposition cell was set up and operated to obtain metal or higher purity for studying the nitrogen-zirconium and oxygen-zirconium system (TID-3010).

495. ___. Zirconium Alloy Project, Report No. 2. Foote Mineral Co., ATI-90438, Mar. 13, 1950, 22 pp.

Discusses the progress in research on a zirconium alloy to determine its physical characteristics. Quenching either iodide bar or arc-melted zirconium from above the transformation temperature increased its hardness and somewhat decreased its ability to withstand cold deformation. Initial hardness of arc melts was a function of the nitrogen and oxygen content. Good rollability was not obtained on ingots containing more than 0.5 percent total oxygen and nitrogen content. Regarding the oxidation characteristics of three lots of iodide zirconium metal containing increasing amounts of aluminum, no mathematical equation was found that would define the curves, but the rate was probably a parabolic function of time and temperature modified by aluminum content. One deposition of high-hafnium (80 percent) zirconium (20 percent) was made to determine the conditions for deposition (TID-3010).

496. ___. Zirconium Alloy Project, Report No. 3. Foote Mineral Co., ATI-90559, May 10, 1950, 27 pp.

Heat-resistance study of arc-melted zirconium alloys containing beryllium, niobium, tantalum, and aluminum showed that one of these metals increased resistance to air oxidation of zirconium at 400, 600, and 750° C. Some work was done to determine the effect of oxygen and nitrogen on the tensile properties of zirconium. Additions of aluminum and beryllium to zirconium impaired the oxidation resistance of zirconium.

Additions of niobium and tantalum appeared to decrease the attack of steam at 600° F. (TID-3010).

497. LITTON, F. B. Zirconium Alloy Project, Report No. 4. Foote Mineral Co., ATI-89912, July 10, 1950, 22 pp.

Tensile test and oxidation data are reported on arc-melted ternary zirconium-oxygen-nitrogen alloys. Based on oxygen and nitrogen contents as determined chemically, the effect of nitrogen in raising the tensile strength and decreasing oxidation resistance in air (2 hours at 750° C.) was more pronounced than similar amounts of oxygen. Increasing oxygen at relatively low concentrations of nitrogen (less than 0.05 percent), did not appear to decrease oxidation resistance. In other series the amount of oxidation generally increased with tensile strength. The elongation decreased rapidly with small additions of either oxygen or nitrogen but remained at approximately 15 percent for alloy additions corresponding to from 60,000- to 100,000-p.s.i. tensile strength. Work will continue to convert the sponge to essentially pure iodide zirconium. Iodide metal deposits from high-hafnium zirconium (30 percent zirconium) sponge resulted in preparation of 2 rods weighing 31 grams. The Vicker's hardness varied from 197 to 221. Each rod was cold-malleable to 23-percent reduction.

498. ___. Zirconium Alloy Project, Report No. 5. Foote Mineral Co., ATI-92375, NP-3308, Sept. 10, 1950, 9 pp.

Work was completed on the preparation of high-purity zirconium according to contract provisions. A total of 6.91 pounds of low hafnium-zirconium metal was produced in metal deposition tubes, which analyzed 99.86 zirconium. Hafnium is included, but oxygen, nitrogen, and hydrogen are excluded. Inasmuch as the average Vicker's hardness on the as-deposited metal was 90.6, it was believed that the gas content did not exceed specifications. The selected material submitted to Wright Field analyzed 99.9 percent zirconium and had an average Vicker's hardness of 86.0 (TID-3010).

499. ___. Zirconium Alloy Project, Final Summary Report for Oct. 18, 1949, to Oct. 18, 1950. Foote Mineral Co., ATI-93544, NP-3286, Nov. 17, 1950, 59 pp.

High-purity zirconium and hafnium metals were produced from commercial $ZrCl_4$ containing 3.0 percent $HfCl_4$. The metals were separated from each other by a fractional-distillation procedure. The products from the final distillation step were $3ZrCl_4.2POCl_3$ and $3HfCl_4.2POCl_3$, respectively. These complexes were decomposed to yield substantially pure $ZrO_2$ and $HfO_2$. The oxides were mixed with carbon and chlorinated at 950° C. $ZrCl_4$ was reduced to crude zirconium metal by sodium at 800° C. $HfCl_4$ was converted to crude metal by reacting it with magnesium metal at an initial temperature at 650° C. The crude metals were then refined by the iodide process. The work-hardening curves for as-deposited and arc-melted iodide zirconium were obtained. Maximum hardness resulted when cold reduced 70 and 60 percent, respectively. Quenching from above the transformation (900° C.) increased the hardness of both materials. Quenching from 700° C. decreased the hardness of arc-melted ingot. The following properties were measured for pure zirconium metal: (1) Hardness - Vicker's 90.1, Rockwell A 20.9; (2) penetration, 0.35 mm. at 750° C. and also at 950° C. for 2 hours in still air; (3) melting point, 1,764° C.; (4) transformation temperature, 807.8° C.; and (5) lattice parameters, c = 5.138 A, a = 3.2247 A, and c/a = 1.591. Nitrogen was observed to harden zirconium more than oxygen. The ratio was 1:2.5 in the concentration range investigated. Zirconium containing oxygen and nitrogen as alloy additions had very satisfactory tensile properties. The tensile properties of an annealed alloy containing 0.299 percent oxygen and 1.03 percent nitrogen (reported analyses) were as follows: Tensile strength, 106,000 p.s.i.; yield strength (0.2 percent), 76,000 p.s.i.; elongation (2 inches), 14 percent. Small concentrations of nitrogen and aluminum decreased the resistance of zirconium to oxidation. Tests indicated that oxygen, tantalum, and niobium may be beneficial (TID-3010).

LITZ, L. H. See abs. 775.

LoCASCIO, C. See abs. 103.

LOEB, A. L. See abs. 5.

LOHR, W. See abs. 2.

LOWE, A. J. See abs. 561.

LUDEWIG, W. H. See abs. 158.

500. LUNDELL, G. E. F., AND KNOWLES, H. B. Determination of Zirconium in Steel. Jour. Ind. Eng. Chem., vol. 12, No. 6, June 1920, pp. 562-567.

A critical review of published and theoretical methods for the determination of zirconium in steels and a method for the determination of silicon, aluminum, titanium, and zirconium in steels containing other probable or possible alloying elements such as tungsten, chromium, vanadium, phosphorus, molybdenum, copper, nickel, cobalt, uranium, and cerium.

501. LUNDIN, C. E., McPHERSON, D. J., AND HANSEN, M. System Zirconium-Silicon. (Ch. in Zirconium and Zirconium Alloys.) Am. Soc. Metals, Cleveland, Ohio, 1953, pp. 208-221.

The phase diagram of the zirconium-silicon system was determined, with particular emphasis on the zirconium-rich portion. The principal methods used were metallography of cast and heat-treated specimens, detection of incipient melting, thermal analysis, and X-ray diffraction analysis. The alloys were prepared under protective helium atmospheres in a nonconsumable-electrode arc furnace.

502. LUSTMAN, B. Effect of Nitrogen and Carbon on the Corrosion of Zirconium in 600° F. Water. Westinghouse Elec. Corp., WAPD-RM-17, July 26, 1950, 16 pp.

Development of methods for the fabrication of fuel elements for the Mark 1 Naval Reactor.

LYNCH, J. F. See abs. 509.

503. LYNCH, J. F., SCHOFIELD, H. Z., AND AUSTIN, C. R. Fundamental Studies of Ceramic Materials. Summary Report, January 1946 to October 1947. Battelle Mem. Inst., NP-215, October 1947, 40 pp.

Raw materials of relatively pure $Al_2O_3$, BeO, or $ZrSiO_2$, encompassing a limited range of grain sizes, were formed into specimens by dust at pressures ranging from 5,000 to 30,000 p.s.i., and were burned at temperatures of 3,100° and 3,300° F. The physical and mineralogical properties at room temperature and the strength at room and at elevated temperatures were determined for the burned specimens. Dense $ZrSiO_4$ bodies of good strength were not obtained by burning at 3,100° F.; moreover, burning at 3,300° F. caused dissociation of the $ZrSiO_4$ to $ZrO_2$ and $SiO_2$ glass, and the resulting specimens were cracked (TID-3010).

504. ___. Fundamental Studies of Ceramic Materials. Progress Report, Mar. 1 to Mar. 31, 1948. Battelle Mem. Inst., NP-606, Apr. 16, 1948, 11 pp.

Progress report on experimentation on alumina, zircon, and beryllia.

505. ___. Fundamental Studies of Ceramic Materials. Progress Report, May 1 to May 31, 1948. Battelle Mem. Inst., ATI-178126, June 16, 1948, 16 pp.

Progress report on experimentation on alumina, zircon, and beryllia. TAM (Australian) granular zircon was investigated, and a chemical analysis indicated that the content of mineral zircon in this material was almost 99 percent and the major contaminant free silica.

506. LYNCH, J. F., SCHOFIELD, H. Z., AND AUSTIN, C. R. Fundamental Studies of Ceramic Materials. Progress Report, July 1 to July 31, 1948. Battelle Mem. Inst., AD-40769, Aug. 16, 1948, 7 pp.

Preliminary fabrication studies were made of the work on $ZrSiO_4$ bodies in which the raw material was prepared by two different degrees of extrusion and slip casting. When the specimens were matured at 3,100° F., the modulus of rupture values did not vary widely with the change in forming method, although bulk density values were higher and the apparent porosity lower for the specimens formed from finer material. Examination of the specimen and data indicated overfiring of the structure at this temperature of maturing (TID-3010).

507. LYNCH, J. F., AND SCHOFIELD, H. Z. Fundamental Studies of Ceramic Materials. Progress Report, Aug. 1 to Aug. 31, 1948. Battelle Mem. Inst., ATI-178129, Sept. 16, 1948, 6 pp.

Continued investigation of the purity of available zircon supplies showed appreciable amounts of quartz in two recent shipments of TAM granular zircon when sharp separations were made by "sink and float" in a heavy liquid. A quantity of the raw material was purified by this separation method for use in appraising the effect of this impurity in fired specimens.

508. LYNCH, J. F., DUCKWORTH, W. H., AND SCHOFIELD, H. Z. Fundamental Studies of Ceramic Materials. Progress Report, Oct. 1 to Oct. 31, 1948. Battelle Mem. Inst., ATI-179280, Nov. 16, 1948, 10 pp.

Progress report on the work being conducted on alumina, zircon, and beryllia. Specimens were prepared from TAM unpurified zircon containing 1.2 percent quartz and purified zircon. Results indicate that firing the samples for 3 hours at 3,000° F., a maturing treatment, did not dissociate the zircon to a significant degree. The observed properties were not affected by the purification of the raw material but were affected by the changes in the fineness of milling the raw material and in the forming method.

509. SCHOFIELD, H. Z., LYNCH, J. F., AND DUCKWORTH, W. H. Fundamental Studies of Ceramic Materials. Final Summary Report, January 1946 to March 1949. Battelle Mem. Inst., NP-1267, Mar. 31, 1949, 124 pp.

Summarizes the work conducted on bodies of alumina, zircon, and beryllia in an investigation to obtain fundamental data on the potentialities of such materials from the standpoints of high temperatures, strength and resistance to creep, and resistance to thermal shock. The investigations were carried out on bodies formed from powders ranging from <1 to 44μ by dust pressing, plastic extrusion, and slip casting.

510. LYONS, L. A. Australian Beach Yields Wonder Metal. Min. World, June 1954, pp. 56-60.

A report on Australian beach sands, which are the largest known source of rutile in the world today. From this mineral comes titanium and zircon.

M

MACE, W. _See_ abs. 298, 299.

MACK, E. L. _See_ abs. 286.

MACK, J. E. _See_ abs. 36.

MÄKELÄ, K. _See_ abs. 240.

511. MAGEL, T. T., KULIN, P. A., AND KAUFMANN, A. R. Approach to Melting Reactive Metals Eliminates Use of Refractory Containers. Jour. Metals, vol. 4, December 1952, pp. 1286-1288.

Discusses two melting procedures - drip melting and autocrucible - for reactive metals such as titanium and zirconium. The drip-melting method involves the feeding of a vertical bar of the material to be melted into an induction coil so that the end is melted off continuously and the drops are collected below in a mold. The autocrucible method consists of holding a pancake-shaped induction coil near the flat surface of a horizontal block of the metal to be melted. Describes methods and apparatus used.

**MALLERY, J. H.** See abs. 424.

**MALLETT, M. W.** See abs. 72, 73, 712.

512. **MALLETT, M. W., BELLE, J., AND CLELAND, B. B.** Reaction of Nitrogen With and the Diffusion of Nitrogen in Beta Zirconium. Jour. Electrochem. Soc., vol. 101, No. 1, January 1954, pp. 1-5.

The rate of reaction of nitrogen with high-purity zirconium was determined for the temperature range of 975° to 1,640° C. at 1 atmospheric pressure. The reaction followed a parabolic law, and the parabolic rate constant in $(ml./cm.^2)^2/sec.$ was calculated to be

$$K = 5.^{0} \times 10^{3}\ \rho - 48,000/RT$$

where 48,000 ± 1,500 cal./mole is the activation energy for the reaction. The rate of diffusion of nitrogen in beta zirconium was obtained for the temperature range of 920° to 1,640° C. at 1 atmospheric pressure. Diffusion-rate calculations based on a solution of the usual diffusion equation gave a diffusion coefficient.

$$D = 1.5 \times 10^{-2}\ \rho - 30,700/RT\ cm.^{2}/sec.$$

The energy of activation of diffusion, 30,700 cal./mole, has a probable error of 1,000 cal./mole. The calculated entropy of activation for diffusion is 3.5 cal./mole degree. The limiting solubilities of nitrogen in beta zirconium were determined from the diffusion data. The heat of solution of nitrogen in beta zirconium is 12,900±500 cal./mole.

513. **MALLETT, M. W., NELSON, H. R., AND PAPP, C. A.** Reaction of Zirconium Metal Surfaces With Oxygen. Battelle Mem. Inst., BMI-727, Feb. 25, 1952, 21 pp.

Oxygen reacts with zirconium at rates that appear to be close to parabolic (square-root function of time) at 600° C., decrease to a one-fourth-power function of time at 875° C., and increase to parabolic at above 1,100° C. This behavior, in contrast to expected parabolic rates, is thought to be brought about by some effect of the transition from alpha to beta zirconium (865 ± 10 C.). An empirical equation expressing this behavior is given in the text. Energies of activation at temperatures in the neighborhood of 300° C. (alpha zirconium) and 1,500° C. (beta zirconium) have been approximated as being 16,000 cal./mole and 112,000 cal./mole, respectively. Large probable errors in these values make comparisons with other reported values inconclusive. No pressure dependency of the reaction was observed. A study of the diffusion of oxygen into zirconium involving the use of these samples has been postponed pending the development of a reliable method of analysis for oxygen.

514. **MANDEVILLE, C. E., AND SCHERB, M. V.** Study of the Radiations from Iridium,$^{(194)}$ Iridium,$^{(192)}$ Lanthanum,$^{(140)}$ Antimony,$^{(124)}$ and Zirconium.$^{(95)}$ Phys. Rev., vol. 73, No. 12, June 15, 1948, pp. 1434-1441.

The beta and gamma radiations of radioactive isotopes of zirconium, prepared by slow neutron bombardment in the Clinton pile, were investigated by absorption and coincidence methods. The 63-day activity was found to emit 0.40-Mev. beta rays. The maximum energy of the gamma rays was 0.91 Mev. as measured by coincidence absorption. The beta-gamma coincidence rate was $0.21 \times 10^{-3}$ coincidence per beta ray, independent of the beta-ray energy. The gamma-gamma coincidence rate, greater than the beta-gamma coincidence rate, was $(0.29 \pm 0.02) \times 10^{-3}$ coincidence per gamma ray. The coincidence experiments suggest that the 0.91-Mev. gamma ray is noncoincident with the beta rays and may be related to some other decay process. Chemical purification was carried out in all cases, except that of antimony. The calibration curve for the coincidence absorption counting set is given, as well as a short discussion of some previously measured beta-ray spectra.

515. **MANDEVILLE, C. E., SCHERB, M. V., AND KEIGHTON, W. B.** Study of the Radiations From Columbium (95), Rhenium (188), Osmium (191) and Osmium (193). Phys. Rev., vol. 74, No. 8, Oct. 15, 1948, pp. 888-893.

The characteristic radiations of $Cb^{95}$, $Re^{188}$, $Os^{191}$, and $Os^{193}$ have been investigated by absorption and coincidence methods. Maximum beta-ray energies were determined by aluminum absorption and maximum quantum energies were measured by coincidence absorption of the secondary electrons in aluminum. Beta-beta, beta-gamma and gamma-gamma coincidence rates were measured when possible. $ZrO_2$ (0.1gm.) was added as a carrier, and the precipitate and carrier were fused with $K_2CO_3$. The melt, when cold, was leached with cold water to dissolve the columbium (niobium), which was then precipitated with $SO_2$. The precipitate was ignited to $Cb_2O_5$. This procedure was intended to separate phosphorus, zirconium, copper, and iron from the columbium.

516. **MANDEVILLE, C. E., SHAPIRO, E., MENDENHALL, R. I., ZUCKER, E. R., AND CONKLIN, G. L.** Radiations from $Zr^{97}$ and $Nb^{97}$. Jour. Franklin Inst., vol. 254, November 1952, pp. 381-389.

$Zr^{96}O_2$ (isotopic concentration, 90 percent) was irradiated by slow neutrons in the Oak Ridge pile. The half period of the niobium daughter element, chemically separated from zirconium, was found to be 72.1 ± 0.7 minutes and that of $Zr^{97}$ to be 17.0 ± 0.2 hours. By aluminum absorption and Feather analysis, maximum beta-ray energies of 2.50 Mev. and 1.40 Mev. were measured for parent and daughter element, respectively. Lead absorption of the quantum radiations of the equilibrium mixture indicated a gamma ray at 0.74 Mev. as well as a softer component. Coincidence absorption yielded a maximum gamma-ray energy of 1.42 Mev. The beta-gamma coincidence rate of $Nb^{97}$ was constant, independent of the beta-ray energy and of such magnitude as to suggest that each beta ray is followed on the average by 0.7 Mev. of gamma-ray energy. The beta-gamma coincidence rate of the equilibrium mixture showed tht the hard beta rays of $Zr^{97}$ proceed directly to the metastable state of $Nb^{97}$. Very few beta rays of $Zr^{97}$ are in immediate coincidence with any gamma radiation.

517. **MANNING, D. L., AND WHITE, J. C.** Differential Spectrophotometric Determination of Zirconium. Carbide and Carbon Chemicals Co., ORNL-1725, May 11, 1954, 12 pp.

Differential spectrophotometry has been applied to the determination of relatively high concentrations of zirconium as the alizarin sulfonate complex in 1 M perchloric acid solution. The method is particularly suited for samples where the zirconium concentration is generally known, and its precision compares favorably with the best precision obtainable by gravimetric procedures. There are few interferences; fluoride, sulfate, and phosphate are the primary ones.

518. **MARDEN, J. W., AND RICH, M. N.** Investigations on Zirconium. Jour. Ind. and Eng. Chem., vol. 12, No. 7, July 1920, pp. 651-656.

Discusses several methods of preparing zirconium oxide, pure potassium fluozirconate, and crystalline zirconium-aluminum alloys; also zirconium metal and analytical methods.

519. **MARINSKY, J. A., HUME, D. N., AND BALLOU, N. E.** Preparation of Carrier-Free Zirconium-Niobium Tracer. (Ch. in Radiochem. Studies.) The Fission Products, Nat. Nuclear Energy Series, book 3, vol. 9, No. 6, Mc-Graw-Hill Book Co., Inc., New York, N. Y. (edited by C. D. Coryell and N. Sugarman), 1951, pp. 1514-1516.

A rapid procedure for the preparation of very pure-carrier-free zirconium-niobium tracer involves the chloroform extraction of the cupferrides of zirconium and niobium activities from an irradiated uranyl nitrate solution.

520. MARKWELL, P. Zircon Sands - Occurrence and Uses in Australian Industry. Am. Foundryman, vol. 25, No. 4, April 1954, p. 93.

Mineralogy, occurrence, and commercial deposits of zircon sand in Australia are briefed, and properties such as refractoriness, conductivity, density, expansion, and resistance to wetting by molten metal are discussed. Typical mixtures for green sand, cores, mold and core washes, and parting dust are given.

521. MARMIER, P., AND BOEHM, F. Energy Levels of Hafnium$^{177}$. Phys. Rev., vol. 97, No. 1, Jan. 1, 1955, pp. 103-104.

The nuclear spectrum of lutetium$^{177}$ has been investigated. Three excited levels of hafnium$^{177}$ have energies of 112.97 kev., 249.69 kev., and 321.33 kev. A decay scheme is proposed.

MARTIN, D. W. See abs. 162.

522. MARTIN, S. L. Vacuum Technique. Chem. and Proc. Eng., vol. 34, No. 9, September 1953, pp. 276-279.

Reviews new advances in high-vacuum techniques, pump design, vacuum gages, and industrial applications to vacuum metallurgy. Discusses application of vacuum technique to the production of zirconium, molybdenum, and titanium.

See also abs. 78.

MARTIN, S. L. H. See abs. 330.

523. MARTIN, S. L. H., AND REES, A. L. G. Interpretation of the Solubility of Hydrogen in Zirconium. Trans. Faraday Soc., vol. 50, No. 4, April 1954, pp. 343-352.

The pressure and temperature dependence of the solubility of hydrogen in zirconium and zirconium + oxygen solid solutions has been interpreted in terms of a statistical-mechanical theory of two-component interstitial solid solutions. The interpretation is consistent with the X-ray data on the phases in the zirconium + hydrogen system. The two-phase region lying between the compositions ZrH and $ZrH_2$ is reproduced satisfactorily in the calculated isotherms. The derived energy parameters lead to a value for the heat of formation of $ZrH_2$ of 41.4 kcal. mole$^{-1}$, in good agreement with the value determined calorimetrically. The effect of oxygen on the initial solubility of hydrogen in zirconium appears to be due to the blocking of sites normally available to hydrogen atoms by neighboring oxygen atoms; the saturation solubility is determined by the amount of free metallic zirconium remaining after separation of the oxygen as $ZrO_2$.

524. MASSACHUSETTS INSTITUTE OF TECHNOLOGY. Seventeenth Progress Report, July 1, 1949, to July 1, 1950. NP-1777, July 1, 1950, 219 pp.

Zirconium has been found to give a brilliant green fluorescence under ultraviolet irradiation with morin in acid solution. By control of the acidity, the fluorescence of almost all other cations can be suppressed. The reaction is extremely sensitive, submicrogram amounts of zirconium being readily measurable. A systematic study of the conditions governing the reproducibility of the fluorescence is being made. It has been shown that acidity, time, temperature, morin concentration, the presence of organic solvents, and the presence of foreign ions are all significant variables. Optimum conditions of morin concentration and acidity have been selected such that the method gives adequate reproducibility.

525. ___. Eighteenth Progress Report, Oct. 1, 1950. NP-3434, (NP-1879), Oct. 1, 1950, 63 pp.

The 80-hour isomer of $Zr^{89}$ was studied and found to emit positrons of 0.905 Mev. (max.) and gamma rays of 0.914 Mev., as well as a considerable number of conversion electrons corresponding to the same transition. The gamma rays must be emitted in an isomeric transition, since they do not coincide either with positrons or with X-rays. A detailed study was made of the variables that influence the effectiveness of the method of separation of zirconium from hafnium by means of cation-exchange resin. The variables included the nature of the complexing agent and its concentration, the acidity of the medium, the ratio of resin weight to solution volume, and the temperature. Conditions most favorable for separating zirconium from hafnium were found in the case of an eluant 0.1M in citric acid and 0.5M in $HNO_3$. The effects of the variation in the resin-weight:solution-volume ratio and the temperature were found to be relatively unimportant over the range studied. Confirmation of the conclusions drawn from the batch experiments was provided by several column runs in which a column of resin 15 cm. long and 3 $cm.^2$ in cross-sectional area was used. A plot of the volume of eluant versus zirconium or hafnium content per unit volume of eluant showed two widely separated peaks, which indicated that a very satisfactory degree of separation of these elements was attained (TID-3010).

**MATEOSIAN, E. der** See abs. 300.

526. **MATERIALS AND METHODS.** Hafnium Helps Refractories. Vol. 39, No. 4, April 1954, pp. 232, 236.

Reviews experiments carried out to determine the permissible hafnium content in zircon and zirconia refractory material.

527. ____. Zirconium. Vol. 34, No. 6, December 1951, pp. 94-96.

Brief discussion of the properties, processing, and applications of zirconium.

**MATHEWS, D. H.** See abs. 78.

528. **MATTHIAS, B. T.** Empirical Relation Between Superconductivity and the Number of Valence Electrons per Atom. Phys. Rev., vol. 97, No. 1, Jan. 1, 1955, pp. 74-76.

The relation between the transition temperature of a superconductor and its number of valence electrons/atom has been investigated. Optimum conditions for the occurrence of superconductivity seem to exist for 5- and 7-valence electrons/atom.

529. **MAURICE, O. D.** Transport and Deposition of the Non-Sulfide Vein Minerals. V. Zirconium Minerals. Econ. Geol., vol. 44, 1949, pp. 721-731.

The synthesis and stability of zirconium minerals were studied in aqueous solutions at a temperature of 400° C. and at a pressure of 900 atmospheres. The compositional fields of stability of the minerals zircon and baddeleyite are outlined approximately. Zircon has a wide field of stability in acid solutions, but its field of stability in alkaline solutions is restricted to limits close to the neutral point. Baddeleyite has a restricted field in acid solutions and a very wide one in alkaline solutions. At least 4 zircono-silicates were obtained as products; 3 of these have not been described in the literature. Solubility tests showed that zirconium compounds are insoluble in alkaline solutions but are very soluble in dilute HCl solutions. From these tests and from the other experimental data, some geological conclusions were drawn regarding the occurrence of zirconium minerals and the nature of the solutions which transported the elements.

**MAXWELL, R. D.** See abs. 277.

**MAZZA, E. N.** See abs. 410.

530. **McALLISTER, M. H.** Production of Zirconium Oxide. Field Information Agency, Tech. (Office of Military Govt. for Germany (U. S.)), FIAT Final Rept. 1048, Jan. 31, 1947, 5 pp.

Original from THE OHIO STATE UNIVERSITY

Describes production of high-purity zirconium oxide as practiced by the Oranienburg Plant of Auergesellschaft A. G., using as raw materials both zircon and favas.

531. McBERTY, F. H. Anhydrous Chlorides Manufacture. Field Information Agency, Tech. (U. S. Dept. of Commerce), FIAT Final Rept. 774, May 7, 1946, 29 pp.

Equipment and process details for manufacturing anhydrous chlorides by high-temperature chlorination at several plants of the I. G. Ferbenindustrie. Operations described are: Aluminum trichloride at Ludwigshafen; iron trichloride at Bitterfeld; silicon tetrachloride at Rheinfelden; and titanium tetrachloride, zirconium tetrachloride, and zirconium oxychloride at Leverkusen.

532. McCARTHY, J. A. Search for Double Beta-Decay in $Sn^{124}$ and $Zr^{96}$. Phys. Rev., vol. 90, No. 5, June 1, 1953, pp. 853-857.

If double beta-decay takes place without the emission of neutrinos, the total kinetic energy of the two emitted electrons will be constant. The half life would be of the order of $10^{16}$ years for 1.5-Mev. available energy or $10^{14}$ years for 3.5-Mev. available energy. $Sn^{124}$ and $Zr^{96}$ have been studied for evidence for such a process. A lower limit of $1.5 \times 10^{17}$ years is set on the half life for double beta-decay of $Sn^{124}$, which has 1.5 ± 0.4-Mev. available energy. In the case of $Zr^{96}$, which has 3.4 ± 0.3-Mev. available energy, the results indicate a lower limit of $2 \times 10^{16}$ years for double beta-decay. The results also indicate the presence of a slight activity of $6 \pm 2 \times 10^{16}$ years half life (if attributed to $Zr^{96}$) at 3.8 ± 0.5 Mev. with an energy spectrum and coincidence nature compatible with the predictions for double beta-decay. Further experimentation is necessary to establish the existence and nature of this activity.

533. McCLAIN, J. H., AND NELSON, R. W. Some Useful Applications of Zirconium. Bureau of Mines Inf. Circ. 7686, 1954, 7 pp.

Throughout the various processing steps necessary for the production of zirconium, there are many corrosive atmospheres, solutions, and conditions that defy the usual or normal materials of construction and make the Kroll process a useful proving ground for practical applications of zirconium. In the past, ordinary steel construction was employed to expedite the fabrication of equipment needed to meet immediate production demands. In other instances the finest material available was employed to meet definite conditions, with the knowledge that failure sometimes was inevitable over a period of time in spite of careful selection. Zirconium metal has been used with a high degree of success in solving these problems. This report describes those applications but does not attempt to evaluate the corrosion rates in the usual finite terms of the corrosion expert.

534. McCLINTON, L. T., AND SHUBERT, J. Acute Toxicity of Some Zirconium and Thorium Salts in Rats. Argonne Nat. Lab., MDDC-1636, ANL-HDY-382, Nov. 23, 1947, 10 pp.

The acute toxicity in rats of the citrate and gluconate salts of zirconium and the citrate salt of thorium have been studied. The salts were administered by intraperitoneal injection in large single doses and in divided doses over an extended period. The $LD_{50}$'s and the standard errors for the experiments were as follows: Zirconium (citrate salt), 1.710 mgm./kgm. ± 80; zirconium (gluconate salt), 247 mgm./kgm. ± 40; thorium (citrate salt), 68 mgm./kgm. ± 12. Rats that survived 36 hours following the injection of the zirconium and thorium salts invariably recovered and exhibited no toxic symptoms 6 months later. No effect of zirconium (citrate) on the blood nor any histological damage was found. As much as 3.650 mgm./kgm. of zirconium (citrate) was tolerated by the rats when administered by intraperitoneal injection once daily in concentrations of 450 mgm./kgm.

535. McCREIGHT, L. R. Effects of Prolonged Heating on Five Pure Oxide Bodies. Illinois Univ., NP-375, May 27, 1948, 21 pp.

Pellets of $Al_2O_3$, BeO, MgO, lime-stabilized $ZrO_2$, and a BeO-$Al_2O_3$-MgO body were prepared from commercial materials by regular processing methods. All pellets were fired to proper maturing temperatures to render them nonabsorbent, but the $ZrO_2$ still had 5.5 percent absorption after heating for 100 hours at 2,000, 2,250, 2,500, 2,750, and 3,000° F. The effects of prolonged heating were not particularly noticeable on the stabilized $ZrO_2$ upon recrystallization and volatilizing (TID-3010).

McDONALD, L. A. See abs. 484.

536. McDONALD, M. C., SUTTON, E. E., AND McLAY, A. B. Arc and Spark Spectra of a Number of Elements in the Lower Quartz Spectral Region. Trans. Roy. Soc. Canada, vol. 20, sec. III, 1926, pp. 313-322.

It is evident that very few strong lines are in the arc or the spark spectra of any of the elements investigated. This probably signified that the ionization potentials both of the normal and ionized atoms are fairly low and that most of the important wavelengths will be well up in the visible regions of the spectrum. A glance at the existing wavelength tables in the region of the longer wavelengths for a number of these elements showed that this seems to be the case.

McDONOUGH, R. See abs. 3.

McGINNIS, W. J. See abs. 756.

McGUIRE, J. C. See abs. 735.

537. McKEE, J. H.; AND ADAMS, A. M. Physical Properties of Extruded and Slip-Cast Zircon With Particular Reference to Thermal Shock Resistance. Trans. British Ceram. Soc., vol. 49, 1950, pp. 386-407.

Describes the preparation of high-grade refractory bodies by extrusion and slip-casting techniques. Some physical properties of the fired material, of which the apparent pososity varied between 16.5 and 25.5 percent and the bulk density between 3.48 and 3.94 gm./cc. have been investigated. For separately fired batches the mean values of tensile strength, measured by a four-point bending method, varied from 3.3 to 7.5 t.s.i. and values of Young's modulus ranged from 5.7 to 8.75 x $10^3$ t.s.i. At room temperature the strength was found (in the later batches) to be proportional to Young's modulus, the ratio corresponding to a critical elongation of 0.09 percent. Machining the fired rods reduced the modulus more (in proportion) than the strength. At 1,000° C. the strength decreased to 30 to 40 percent. The thermal shock resistance was also investigated and was found not to differ significantly for the extruded and slip-cast materials. Machining extruded zircon after firing does not affect its thermal shock resistance, but round-section material is superior to square; thermal shock has a greater effect on the strength than on Young's modulus. Recovery from thermal shock can be brought about by refiring the shocked specimens. Zircon is superior to alumina in thermal-shock resistance, and this superiority is attributed chiefly to the low coefficient of thermal expansion, which was measured and found to be 4.2 x $10^{-6}$/° C.

McKINSTRY, H. A. See abs. 338.

McKINNEY, D. S. See abs. 672.

McLAY, A. B. See abs. 536.

538. McLENNAN, J. C., HOWLETT, L. E., AND WILHELM, J. O. Electrical Conductivity of Certain Metals at Low Temperatures. Trans. Roy. Soc. Canada. vol. 23, sec. III, 1930, pp. 287-306.

Temperature-resistance measurements were made between room temperature and 2.2° K. on the metals molybdenum, tantalum, hafnium, uranium, titanium, tungsten, magnesium, zirconium, niobium, and lead deposited in thin films on zinc; also on mischmetal and on the eutectic alloy of cadmium and antimony and on sodium lead supposedly having the chemical composition $Na_2Pb_5$. The metals molybdenum, hafnium, uranium, titanium, tungsten, magnesium, and zirconium gave normal temperature-resistance curves with residual resistances at very low temperatures.

539. McMAHON, J. F., SHAW, L. I., WEST, R., TINKLEPAUGH, J., AND SIBERSTEIN, F. Summary of Progress Rept., June 24, 1946, to June 24, 1947. New York Coll. Ceram., NP-545, 15 pp.

Additions of 0.5, 1.0, and 2.0 percent of $ZrO_2$, $SiO_2$, and $Cr_2O_3$ were made to pure $Al_2O_3$ samples. The batches were mixed by dry-ball milling and then were mixed with a 5-percent dextrin solution. Bars, 1/2 inch by 1/2 inch, by 4 inches, were dry pressed at 5,000 p.s.i., and after drying were divided into 2 groups. One group was fired at 1,760° C. and the other at 1,815° C. Physical data obtained from these bars are tabulated. This includes porosity and specific gravity (TID-3010).

McPHERSON, D. J. See abs. 212, 501, 671.

540. McPHERSON, D. J., AND HANSEN, M. System Zirconium-Tin. (Ch. in Zirconium and Zirconium Alloys.) Am. Soc. Metals, Cleveland, Ohio, 1953, pp. 222-238.

The highly reactive zirconium-tin alloys were prepared and heat treated under protective conditions. The phase diagram was established, based on micrographic and X-ray diffraction analysis, metallographic detection of incipient melting, and thermal analysis.

McQUARRIE, M. C. See abs. 601.

541. McVEY, W. H. Zirconium Chemistry, the Nitrate and Thenoyl Trifluoracetone Complexes and the Hydrolytic Species. General Electric Co., HW-21487, June 29, 1951, 22 pp.

Only the first and second nitrate complexes, $ZrNO_3^{+3}$ and $Zr(NO_3)_2^{+2}$ were found to be important in nitric acid solutions up to 4.0 molar in concentration. At an ionic strength of 4.0, the equilibrium constants for the formation of these complexes are 0.586 and 0.090, respectively; these values are corrected for the presence of the aqueous TTA complex. The equilibrium constant for the formation of the first chelate, $ZrK^{+3}$, is 1,084 at an ionic strength of 4.0. Only the first chelate was observed at TTA concentrations up to $10^{-4}$M. Only two hydrolytic species of zirconium, $Zr^{+4}$ and $Zr\ (OH)_2^{+2}$, were observed in dilute acid solution. The equilibrium constant for the formation of $Zr\ (OH)_2^{+2}$ at ionic strength 4.0 increases from 0.40 to 0.65 as the zirconium concentration increases from 1.25 to 2.50 x $10^{-4}$M, which indicates that polymerization accompanies hydrolysis. The amount of zirconium monomer in a solution 0.0625M in zirconium in 2M perchloric acid was found by optical density measurements to be 14.7 percent, in good agreement with Connick and Reas' value of 14 percent obtained by a solvent-extraction method.

542. MEERSON, G. A., AND SAMSONOV, G. V. Preparation of Zirconium Carbide in Vacuum. Jour. Appl. Chem., U. S. S. R., vol. 25, No. 7, July 1952, pp. 823-826.

The rate of increase of pressure of CO evolved in heating $ZrO_2$ and lampblack shows that the reaction $ZrO_2 + 3C = ZrC \cdot 2CO$ is the total one for consecutive reactions beginning with $Zr_2O_3$ and ZrO formations. At atmospheric pressure the range 1,900°-2,100° C. is required for such ZrC preparation, but 165°-1,700° C. is enough in vacuum. The equilibrium existence of $ZrO_2$ and ZrC is ruled out. Graphs and tables are given.

543. MEGGERS, W. F. Wave-Length Measurements in the Arc and Spark Spectra of Hafnium. Nat. Bureau of Standards Jour. Res., vol. 1, 1928, pp. 151-187.

Using the purest available samples of hafnium salts, the arc-and-spark spectra characteristics of this element were photographed with concave-grating and quartz-prism spectrographs. Wavelength measurements were made on about 2,100 lines; 609 of these were discarded as impurities, identified mainly as columbium (niobium), zirconium, and titanium. Nearly 1,500 lines remain to describe the hafnium spectra between the wavelength limits 2155.72-A in the ultraviolet and 9250.27 in the infrared. In this investigation, an attempt has been made to improve upon an earlier description of these spectra (1) by extending observations to shorter and longer waves, (2) by increasing the precision of the wavelength measurements of ±0.01-A, and (3) by making a more critical differentiation between lines characterizing neutral atoms (hafnium I) and those ascribable to ionized atoms (hafnium II). Comparison of these results with the earlier measurements of zirconium spectra proves that hafnium was invariably present as an unrecognized impurity. The most sensitive hafnium I and hafnium II lines for spectrochemical identification are tentatively selected. The stronger hafnium II lines are identified with faint Fraunhofer lines in the sun's spectrum.

544. MEGGERS, W. F., AND KIESS, C. C. Spectral Structures for Elements of the Second Long Period. Jour. Opt. Soc. Am. and Rev. Sci. Instruments, vol. 12, No. 5, May, 1926, pp. 417-447.

Interim report concerning the regularities of the arc-and-spark spectra of several elements. The wavelength measurements for zirconium have been made in the regions from 2,100 to 9,300 A for the arc spectrum and from 2,060 to 4,927 A for the spark spectrum.

545. MEGGERS, W. F., AND SCRIBNER, B. F. Regularities in the Arc Spectrum of Hafnium ($Hf_1$). Nat. Bureau of Standards Jour. Res., vol. 4, 1930, pp. 169-175.

The first regularties among lines characterizing the first spectrum of hafnium ($Hf_1$) have been discovered. Combinations of 7 low-energy levels with higher excited states establish more than 200 lines. Innerquantum numbers have been assigned to the energy levels, and tentative identification of the seven low levels is suggested.

546. ____. Regularties in the Spark Spectrum of Hafnium (HfII). Jour. Opt. Soc. Am. and Rev. Sci. Instruments, vol. 17, No. 2, August 1928, pp. 83-90.

Assuming that enhanced lines developed with great intensity in the arc as well as in the spark spectrum must involve low-energy states of the ionized atoms, the relative values of 16 low levels combining with 27 higher energy states have been established. These combinations establish 206 lines of the HfII spectrum. Although it is impossible with Zeeman effects to assign all the quantum numbers to each level, it appears likely that the normal state of the hafnium atom is represented by a $^2D$ spectral term arising from the electron configuration $d^2s$. (Chem. Absts.)

547. MEHROTRA, R. C. Dialcoholation eactions of the Alkoxides of Group IV Elements. Jour. Indian Chem. Soc., vol. 31, No. 11, November 1953, pp. 732-734.

It has been shown that on treatment of titanium and zirconium ethoxides and isopropoxides with hydrogen chloride, dichloride, and trichloride derivatives of titanium and zirconium are respectively formed. The reaction of zirconium eta propoxide with hydrogen chloride gives an equimolecular mixture of the dichloride and trichloride zirconium derivatives. In contrast to the above it has been shown conclusively that no reaction occurs between eta butyl orthosilicate and hydrogen chloride. These reactions throw fresh light on the reactivity of the tetrachlorides of these elements towards alcohols.

548. ____. Reaction of the Alkoxides of Titanium, Zirconium, and Hafnium With

Esters. Jour. Am. Chem. Soc., vol. 76, No. 8, Apr. 20, 1954, pp. 2266-2267.

This report shows that the alkoxides of titanium, zirconium, and hafnium react with organic esters as

$$M(OR)_4 + 4R'OOCMe \rightleftarrows M(OR)_4 + 4ROOCMe.$$

The reaction can be pushed to completion if the organic ester (ROOCMe) formed is more volatile and can be fractionated out of the system.

See also abs. 93, 95, 96, 97, 98.

549. MEISTER, G. Production of Rarer Metals. Westinghouse Elec. Corp., MDDC-1673, undated, decl. Feb. 11, 1948, 11 pp.

It was possible to prepare pure zirconium by reducing the oxide with calcium or magnesium contained in a molybdenum crucible in an atmosphere of argon. This assembly was surrounded with a special glass bulb that has the high-temperature-resistant qualities of quartz, and the crucible was heated by high frequency. Any excessive vaporization of calcium or magnesium at 1,000 or 1,200° C. was suppressed by the inert-gas filling. It was possible to reduce considerably the contamination with active gases as $O_2$ and $N_2$. The metal was obtained in powder form and compressed in hardened steel dies into compacts in a hydraulic press at 40 to 50 p.s.i. These compacts are strong and can be handled readily. They may be sintered or melted in high vacuum on a suitable refractory. The vacuum should be $10^{-3}$ mm. or better. The analysis of this metal powder showed on the average impurities of carbon, 0.02 percent; SiO, 0.02 percent; iron, 0.04 percent; calcium, 0.10 percent; and titanium, 0.01 percent (TID-3010).

550. ___. Production of Thorium, Zirconium and Uranium. Metal Prog., vol. 53, No. 4, April, 1948, pp. 515-520.

A brief summary of the production and properties of zirconium.

MELLEN, G. L. See abs. 196, 197, 198, 199, 200, 201.

551. MELZER, W., AND CHAMBERS, G. H. Zirconia in Brazil. Foote Prints, vol. 14, No. 1, 1941, pp. 17-21, 24-26.

Occurrences, history, and mining of zirconia in Brazil.

MENDEL, M. G. See abs. 448.

MENDENHALL, R. I. See abs. 516.

552. MENIS, O. Determination of Zirconium by the Chloranilic Acid Method. Carbide and Carbon Chem. Co., ORNL-1626, Apr. 7, 1954, 27 pp.

The use of the zirconium chloranilate complex, of Thamer and Voight, for the estimation of zirconium in low concentrations, of the order of micrograms, was investigated. The optimum conditions, including acid concentration, wavelength, temperature, quantity of reagent, stability, and tolerance for interfering ions have been established. The additive properties of a multicomponent system, consisting of zirconium complex, uranium complex, and excess reagent were studied, and a method was developed for determining zirconium in the presence of relatively high concentrations of uranium. Procedures for eliminating some of the most seriously interfering ions such as $F^-$ and $iron^{+++}$ were developed. The range of zirconium concentration and the degree of precision for this method under optimum conditions are given.

553. METAL INDUSTRY. Powder Metallurgy. Vol. 73, Aug. 6, 1948, pp. 103-105; Aug. 13, 1948, pp. 129-130.

The first International Symposium of Powder Metallurgy was held in Graz, Austria, July 12-17, 1947. At this conference papers were presented on a number of subjects including a description by

J. D. Fast on the production of metals difficult to prepare by normal methods. The preparation of ductile titanium, zirconium, hafnium, and vanadium by the iodide formation and subsequent decomposition was discussed.

554. **METAL INDUSTRY.** Production of Pure Zirconium. Vol. 83, No. 6, Dec. 25, 1953, pp. 522-523.

Progress by Westinghouse in the production of pure zirconium.

555. ___. Zirconium Production by Fused Salt Electrolysis. Vol. 84, No. 22, May 28, 1954, p. 468.

Details of the fused-salt electrolysis process and comparison with the Kroll process.

556. **METALS AND ALLOYS.** Zirconium. Vol. 12, 1940, pp. 348, 350.

Discusses the production and properties of zirconium and its use as a getter material.

**MEYER, D. I.** See abs. 308.

557. **MEYER, H. C.** Zirconia, a New Refractory. Met. Chem. Eng., vol. 12, No. 12, December 1914, pp. 791-793.

History, properties, and uses of zirconia for refractories.

558. ___. Further Notes on the Refractory Properties of Zirconia. Met. Chem. Eng., vol. 13, April 1915, pp. 263-266.

History, properties, and uses of the refractory zirconia.

559. ___. Zirconia: Its Occurrence and Application. Trans. Eng. Ceram. Soc., Oct. 18, 1919; Jour. Soc. Chem. Ind., vol. 37, 1918, p. 698A.

Technology and applications of zirconia.

560. **MICHAELSON, H. B.** Preliminary Survey of Physical and Mechanical Properties of Zirconium. Sylvania Elec. Prod., Inc., Sept. 4, 1951, 17 pp.

A brief survey of the properties of zirconium, with emphasis on the working properties of sheet zirconium.

561. **MILLER, C. C., AND LOWE, A. J.** Qualitative Semimicro-Analysis With Reference to Noyes and Bray's System: The Tantalum and the Tungsten Group. Jour. Chem. Soc., 1940, pp. 1258-1263.

The elements composing the tantalum and the tungsten groups of Noyes and Bray's system have been divided into two groups, differing slightly from those of Noyes and Bray. For mixtures containing not more than 50 mg. referred to the cations, satisfactory methods have been evolved for the detection and approximate estimation of 0.25-50 mg. of antimony, tin, and phosphate; 0.25-10 mg. of molybdenum, tellurium, titanium, tungsten, and zirconium; 0.5-10 mg. of tantalum and niobium; and minor amounts of vanadium (0.25-2 mg.) and bismuth (0.25-0.5 mg.).

562. **MILLER, E. C.** Zirconium and Nuclear Reactors. (Ch. in Zirconium and Zirconium Alloys.) Am. Soc. Metals, Cleveland, Ohio, 1953, pp. 327-340.

Reasons (nuclear, chemical, and mechanical) for the special interest in zirconium and certain other materials for structural use in nuclear reactors, particularly those to be considered for possible use in longer range, large-scale atomic-power production. The improvements in neutron economy and particularly in the effective utilization of the available supply of fertile and fissionable nuclear fuel material that can result from the use of low-neutron cross-section materials are developed in some detail. The more or less commonly available elements are tabulated and compared on the basis of certain of these requirements, and a short list of metallic materials with moderately low neutron cross sections and relatively high melting points was selected, which appear to hold promise for general structural use in power reactors. Additional and alternative factors beyond those of structural-material selection involved in the development of a substantial nuclear-power industry are reviewed. The paper concludes with a résumé of the work that has been done at the Oak Ridge National Laboratory as part of the zirconium development program.

563. MILLER, E. C. Zirconium: Structural Material for Nuclear Reactors. Nucleonics, vol. 11, No. 7, July 1953, pp. 27-31.

Processes for purification, production, and fabrication of zirconium metal, developed, improved, and expanded to a near-commercial scale. Extensive physical, chemical, metallurgical, and engineering data have been accumulated. This article reviews the information pertinent to reactor technology.

564. MILLER, G. L. Development of Melting Techniques for Titanium and Zirconium. Ind. Chem., vol. 30, No. 359, December 1954, pp. 577-584.

This report traces the development of melting techniques for titanium and zirconium and suggests that some of the ingenious methods that were proposed during earlier investigations may eventually lead to the solution of other melting problems. It appears that consumable arc melting will become the standard method.

565. ___. Double Melting Technique Improves Homogeneity and Purity of Zirconium and Titanium Ingots. Iron Age, vol. 174, No. 13, Sept. 23, 1954, pp. 116-119.

Describes a double-melting technique for unalloyed zirconium from sponge. This method permits a recovery of 95 percent in the form of finished ingots free from flaws and results in a saving of considerable metal.

566. ___. Production and Properties of Tantalum and Zirconium. Ind. Chem., vol. 29, No. 345, October 1953, pp. 482-488.

A brief account of the methods for producing tantalum and zirconium. Describes the corrosion resistance of these metals and other properties that influence their use for chemical engineering purposes.

567. ___. Production of Ductile Zirconium. (Ch. in Symposium On Refining Non-Ferrous Metals, London, 1949.) Inst. Min. and Met., 1950, pp. 391-405.

History of metallic zirconium and comparison of the Kroll and van Arkel processes for large-scale production of zirconium. Gives details of the plant and procedure for the Kroll process.

568. ___. Zirconium. Ind. Chem., vol. 26, October 1950, pp. 435-441.

Outlines early methods of preparing zirconium, discusses commercial production, and refers to the properties and application of the metal.

569. ___. Zirconium. Machinery Lloyd, No. 12, 1951, pp. 68-73.

Discusses development of the Kroll process for ductile zirconium and the possibility of its application for low-cost production. Also, outlines its properties, melting, machining, and production.

570. ___. Zirconium. Murex Rev., vol. 1, No. 8, 1951, pp. 184-194.

Details of all phases of production of zirconium and its compounds.

571. ___. Zirconium Production. Metal Ind., vol. 85, No. 6, Aug. 6, 1954, pp. 103-105.

Details of the development of zirconium by the Kroll process to full-scale production.

**MILLER, P. D.** See abs. 641.

572. **MILLIGAN, W. O.** Recent X-Ray Diffraction Studies on the Hydrous Oxides and Hydroxides. Jour. Phys. and Colloid. Chem., vol. 55, 1951, pp. 497-507.

The structures and properties of hydrous and hydrated oxides and hydroxides are of continued interest because of their importance in both pure and applied chemistry. This paper is concerned with recent work on the hydrous oxides and hydroxides. The discussion is limited primarily to X-ray and electron diffraction studies on single oxides such as cupric oxide, alumina, chromia, and the trivalent oxides of indium, scandium, and the rare earths and dual or multiple oxide systems such as $NiO-Al_2O_3$, $BeO-In_2O_3$, $Cr_2O_3-Fe_2O_3$, $Cr_2O_3-ZrO_2$, $NiO-Cr_2O_3$, and $NiO-Cr_2O_3-ZrO_2$.

See also abs. 811, 812.

573. **MILLIGAN, W. O., AND WATT, L. M.** X-Ray Diffraction Studies in the System $NiO-Cr_2O_3-ZrO_2$. Jour. Phys. and Colloid. Chem., vol. 52, 1948, pp. 230-235.

Discusses the phenomenon of mutual protective action against crystallization for the ternary system $NiO-Cr_2O_3-ZrO_2$. The entire range of compositions at a constant temperature level has been systematically studied, using methods previously used in two-component systems.

**MILLIKAN, R. A.** See abs. 92.

**MILLS, G. J.** See abs. 105, 106.

**MILNE, W. L.** See abs. 300.

**MILWEE, J. B.** See abs. 46, 47.

574. **MINERAL INFORMATION SERVICE.** Zirconium. State of California, Division of Mines, Sept. 1, 1954, vol. 7, No. 9, pp. 1-3.

Briefly discusses zirconium and zirconium compounds from the standpoint of properties and production. Detailed information on all phases of the mineral zircon.

575. **MINING JOURNAL (LONDON).** Titanium-Zircon Industry of Australia. Vol. 233, Nov. 12, 1949, pp. 1070-1072.

Summarizes the titanium-zircon industry in Australia, including reserves, occurrences, operating companies, and production.

576. ___. Zirconium as a Coming Metal. Feb. 6, 1953, pp. 157-159.

Although zirconium was first produced more than a century ago, it is only recently that it has become available commercially in ductile form. This article discusses the development of zirconium to its present commercial status, compares the iodide (deBoer) and Kroll processes, and covers refining problems, applications, and properties.

577. **MINING MAGAZINE.** Zirconium. August 1953, pp. 124-125.

Brief survey of development, production, and uses of zirconium.

578. **MITCHELL, L.** Ceramics. Ind. Eng. Chem., vol. 46, No. 10, October 1954, pp. 2056-2064.

The field of ceramics embraces all high-temperature chemistry and physics of nonmetallic materials and the methods and techniques of forming products at high temperatures. The developments of the past 3 years are summarized. Ceramic science deals with many newly discovered, utilized, and synthesized materials used for new developments in electronic, industrial, nuclear-science, aeronautic, domestic, and even agricultural pursuits. The dielectrics, cermets, oxide bodies, and refractory coatings have been most intensively investigated, but some research continues on the more commonplace ceramic products and processes. Included in this report are hafnium and zirconium and its compounds.

579. **MITTLEMAN, P. S.** Decay Scheme of $Zr^{95}$. Phys. Rev., vol. 94, No. 1, Apr. 1, 1954, pp. 99-102.

The decay scheme of $Zr^{95}$ has been studied, using the techniques of beta-ray spectroscopy and beta-gamma angular correlation. The decay of $Zr^{95}$ is found to proceed by 3 beta-gamma cascades. Two of the beta transitions are allowed and proceed to $Nb^{95}$ levels at 722.0-kev. and 754.4-kev. The third beta transition is to a 235-kev. level in $Nb^{95}$. From K-conversion coefficient determinations and shell theory, the 722-kev. and 754.4-kev. levels are both assigned even parity and a spin of 5/2 or 7/2.

580. ___. Radiations From $Zr^{95}$. Phys. Rev., vol. 91, No. 2, July 15, 1953, p. 484.

Studies have been made with a high resolution beta-ray spectrometer of the continuous beta-spectra and the conversion lines resulting from the decay of $Zr^{95}$.

**MODAK, K. V.** See abs. 640.

581. **MONG, L. E., AND DONOGHUE, J. J.** Preparation of Zirconia and Alumina Shapes. Am. Ceram. Soc. Bull., vol. 29, No. 11, November 1950, pp. 405-407.

Describes the preparation of zirconia and alumina refractory shapes. The granular material was plasticized and bonded by adding a compound, of the respective material, that decomposed during firing to form the oxide. Grain-size fractions were proportioned to develop strength. The refractory shapes are used in furnaces where high temperature and large temperature gradients exist.

**MONTALBETTI, R.** See abs. 413.

**MOORE, G. E.** See abs. 451.

**MOORE, J. H.** See abs. 207, 208, 209.

582. **MOORE, J. H., AND DiPIETRO, W. O.** Preparation of Zirconium Metal by Arc Dissociation of Halides. Nat. Res. Corp., Apr. 16, 1953, 25 pp.

A research program was initiated and the problem separated into two projects, one of which was an investigation of the dissociation process and the other an investigation of the continuous-casting unit design. This paper deals only with the dissociation process.

**MOREL, R. W. F., WILLIAMS, G. C., AND RYERSON, F. E.** Study of Selected Metallic Borides, Nitrides, and Phosphides, Final Report. See abs. 48.

**MORRISON, C. Q.** See abs. 285.

**MOSKOWITZ, D.** See abs. 260, 629.

583. **MOSS, M.** Apparatus for Measuring the Thermal Conductivity of Metals in Vacuum at High Temperatures. Rev. Sci. Instruments, vol. 26, No. 3, March 1955, pp. 276-280.

The method of determining the thermal conductivity of a metal with this apparatus consists, essentially, of measuring both the axial temperature gradient and the transfer of heat under steady state conditions in a thermally shielded cylindrical rod of the metal, which is heated at one end and cooled at the other. The objective was to make precise determinations of conductivity without relying on previously established data for standard metals. In certain respects the apparatus embodies simplification of and improvement over other equipment of this type. A calorimetric measurement of heat flow constitutes a distinct advantage of the instrument both as to its simplicity and the fact that it supplies the data necessary for a direct rather than a comparative evaluation of thermal conductivity. Other features include vacuum operation and special instrumentation to facilitate the measurement of temperature differences. Tests have been made on nickel, zirconium, and a zirconium-3-percent-tin alloy from room temperature up to the range between 500 and 700° C. Where comparison is possible, the results are in close agreement with some of the most accurate published data of this type.

584. **MOTE, M. W., FROST, P. D., AND JACKSON, J. H.** Investigation of Zirconium-Cerium Master Alloys for Use in Adding Zirconium to Magnesium. Final Report. Battelle Mem. Inst., NP-4567, AD-11938, Jan. 31, 1953, 19 pp.

The objective of this project was to investigate the use of zirconium-cerium master alloys for introducing zirconium in magnesium. Zirconium-cerium alloys were made in a cold-crucible, tungsten-electrode, inert-atmosphere arc furnace and contained from 10 to 70 percent zirconium. In a preliminary series of magnesium heats zirconium analyses of as high as 0.70 percent were obtained with the use of the zirconium-cerium master alloys. The rate at which the alloys dissolve in magnesium decreased as the zirconium content was increased, so that it was necessary to machine master alloys containing more than 30 percent zirconium to chips. Alloys containing less zirconium, however, dissolved rapidly in the massive state. Experimental magnesium alloys were made with intended compositions of 6 percent zinc, 0.7 percent zirconium, and 0.5, 1.0, and 1.5 percent cerium. None of the alloys had the intended composition. The reason for this is attributed to the fact that stirring was kept to a minimum, and a long settling period was used to avoid dross inclusions. Despite the low zirconium and zinc contents, the mechanical properties of one heat (1022) were outstanding. With an analyzed composition of 4.5 percent zinc, 0.25 percent zirconium, and 1.16 percent cerium, its properties compared favorably with published values as follows:

| Alloy | Ultimate strength, p.s.i. | Yield strength, p.s.i. | Elongation in 2 inches, percent |
|---|---|---|---|
| ZK60 (extruded) | 49,000 | 38,000 | 12 |
| ZRE-1 (cast) | 26,000 | 14,200 | 8 |
| Heat 1022 (extruded) | 43,100 | 36,200 | 21 |

It is significant that commercial high-strength magnesium-zirconium alloys contain at least 0.5 percent zirconium, whereas the experimental alloy contains only 0.25 percent. In addition all alloys exhibited very high elongations. Values up to 33 percent were recorded.

**MOUBIS, J. H. A.** See abs. 408, 615.

**MOWRY, A. L.** See abs. 602.

**MUDD, J. F.** See abs. 46, 47.

**MUEHLHAUSE, C. O.** See abs. 90.

**MUELLER, M. H.** See abs. 471.

**MYERS, F. B.** See abs. 426.

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585. **NADLER, M. R., AND FITZSIMMONS, E. S.** Preparation and Properties of Calcium Zirconate. Ames Lab., Iowa State Coll., ISC-494, June 24, 1954, 19 pp.

Describes preparation of calcium zirconate by solid-state reactions at 1,450°-2,000° C. A very stable material can be prepared by the reaction of calcium carbonate and zirconium oxide, in equimolar proportions, at a final temperature of 1,850° C. Lattice constant values for this material agree with data reported by previous investigators. Results of firing behavior tests indicate that pure

$CaZrO_3$ can be used at temperatures of 1,800° C. or higher. The linear coefficient of thermal expansion over the temperature range 25°-1,300° C. is 11.5 x $10^{-6}$ per °C.

NAGY, J. See abs. 339, 340.

586. NAISH, W. A., CLENNEL, J. E., AND KINGSWOOD, V. S. Metallurgical Analysis. (Sec. in Select Methods of Metallurgical Analysis.) Chapman and Hall Ltd., London, 1953, pp. 41, 267-271, 477-480, 541-543.

Several methods for the metallurgical analysis of zirconium and zirconium oxide.

NAKATA, M. See abs. 362.

587. NATIONAL SAFETY NEWS. Zirconium. May 1949, pp. 39, 40, 42.

Outlines the industrial hazards encountered when handling zirconium powder and discusses shipping, storage, handling, fire extinguishment, and disposal methods.

588. NATURE. Persistent Lines of Hafnium. Vol. 119, No. 2992, Mar. 5, 1927, pp. 352-353.

A number of spectra of zirconium ores and oxides have been examined for persistent lines of hafnium. Wavelengths given by Hansen and Werner (Nature, vol. 112, No. 618, 1923, pp. 618-619, 900-901) were used in the experimentation.

NAUMANN, D. E. See abs. 171.

NEFF, J. M. See abs. 694.

NELSON, H. R. See abs. 513.

589. NELSON, K. E. Properties of Sand Cast Magnesium-Thorium-Zinc-Zirconium Alloys. Jour. Metals, vol. 5, No. 11, November 1953, pp. 1493-1497.

The effect of thorium and zinc variations on the strength and 100-hour creep characteristics of magnesium-thorium-zinc-zirconium alloys was investigated. Optimum resistance to creep at 650° and 700° F. are attainable within a certain range of thorium and zinc contents. This range does not conform to that which develops maximum tensile properties.

590. NELSON, K. E., AND STRIETER, F. P. Casting of Magnesium-Rare Earth-Zirconium Alloys in Sand Molds. Trans. Am. Foundryman's Assoc., vol. 58, 1950, pp. 400-410.

EK30 alloy is comparable in tensile and creep properties to the other alloys in the rare-earth class and is superior to the magnesium-aluminum-zinc systems at elevated temperatures. This conclusion is drawn from data in this paper comparing these properties in AZ92 with the properties of magnesium, 3 to 6 percent rare earth, 0.0 to 3.0 percent zinc and 0.0 to 0.6 percent zirconium. The foundry characteristics of EK30 alloy show it to be about equal in castability to AZ92 and AZ63 alloys. In addition, the experience that has been obtained in production, using the alloying procedures discussed, indicates that it can be handled in a foundry more advantageously than can alloys containing the higher rare-earth or zirconium content.

591. NELSON, R. G., KATO, H., AND CARPENTER, R. L. Mechanical Properties of Consumable-Arc-Melted Kroll-Process Zirconium. Bureau of Mines Rept. of Investigations 5063, 1954, 13 pp.

Discusses the mechanical properties of low-hafnium, arc-melted, Kroll-process zirconium and the effect of temperature on the ultimate strength, yield strength, proportional limit, elongation, hardness, Young's modulus, electrical resistivity, and impact strength. Describes the effects of cold work and annealing on the tensile properties and bend radius and formability as determined by cupping tests. Tensile properties are compared, in part, to those obtained on earlier graphite-melted zirconium and on crystal-bar zirconium.

**NELSON, R. W.** See abs. 533.

**NESTER, W. H.** See abs. 162.

592. **NEWTON, A. S.** Fission of Thorium With Alpha-Particles. Phys. Rev., vol. 75, No. 1, Jan. 1, 1949, pp. 17-29.

The fission distribution of fission of thorium with alpha-particles of average energy 37.5 Mev. has been measured by the chemical method. The distribution found shows that the characteristic dip in the fission-yield mass spectrum has been raised to within a factor of two of the peaks compared to a factor of 600 in slow neutron fission of $U^{235}$. The raise in the dip has caused a corresponding lowering in fission yield of these elements at the peaks. The cross section of fission of thorium with 37.5-Mev. alphas was found to be about 0.6 barn, and the threshold for fission was found to be 23 to 24 Mev.

593. **NICHOLS, E. L., AND HOWES, H. L.** Blue Glow. Jour. Opt. Soc. Am., vol. 6, January 1922, pp. 42-53.

Certain oxides when heated to incandescence emit light of a distinctly bluish cast at temperatures corresponding to the dull red heat of nonselective radiators, which may be referred to as the luminescence of incandescent solids. Measurements were made on the oxides of zirconium and other elements to determine the "blue glow." Results are given in tables, and the experimental methods used are discussed.

594. **NIEMANN, J. T., AND SOPHER, R. P.** Embrittlement of Multipass Welds in Zircaloy-2. Welding Jour., vol. 35, No. 1, January 1956, pp. 27s-31s.

Metallographic examinations of two-pass welds in Zircaloy-2, a zirconium-tin-chromium-nickel alloy, showed that a precipitate of intermetallic compounds was present in the root pass but not in the second pass. Bend tests showed the root of the weld was less ductile than the face. Tests were then made on single-pass weldments to determine: (1) If the precipitate was the result of cooling rate after welding; (2) if ductility could be restored by postweld heat treatment; and (3) the effect of the precipitate on the mechanical properties of weldments. It was found that the amount of precipitate present was a function of cooling rate and that large amounts resulted in lowered bend ductility and tension-impact strength. The study showed that the properties could be restored by postweld heat treatment.

595. **NIEN-T'AI, S., AND BAND, W.** Explanation of Anomalous Thermionic Emission Current Constants. Proc. Cambridge Phil. Soc. (England), vol. 61, 1946, pp. 72-77.

Anomalously large and small values of the constant A in the thermionic current formula for metals can be explained by the usual statistical equilibrium theory if proper consideration is given to the fact that free electrons may be shared by two competing overlapping energy bands. When this theory is developed, a comparatively large temperature variation of the statistical parameter zeta arises which occurs in the Fermi function; when the exact formula is forced into the empirical form with a constant work function, the temperature factor appears as a multiplying factor of the current constant; this factor is greater or less than unity, depending on the nature of the overlapping bands. In particular, the observed values of the constant A for nickel and for hafnium are well explained.

596. **NISBET, J. D., AND HIBBARD, W. R., JR.** Rationalization of Measured High Temperature Properties of Iron-Chromium-Cobalt-Nickel Alloys. Jour. Metals, vol. 5, No. 9, September 1953, pp. 1149-1165.

The high-temperature properties of iron-chromium-cobalt-nickel-base alloys and the effects of hardening-element additions on these properties are rationalized on the basis of general principles of alloying.

597. NONAMAKER, F. C. Technology of Zirconium and Its Compounds. Chem. and Met. Eng., vol. 31, No. 4, July 28, 1924, pp. 151-155.

Discusses historical interest of the development of an element that exhibits properties of interest to many industries.

598. NORTON, F. H. Some Special Refractory Materials. Lexington Project Report, AECD-3424, LP-174, Sept. 28, 1948, 30 pp.

A survey of several refractory materials, including zirconia, zirconates, and zirconium nitrides. Their properties are summarized.

599. NORTON, J. T., BLUMENTHAL, H., AND SINDEBAND, S. J. Structure of Diborides of Titanium, Zirconium, Columbium, Tantalum and Vanadium. Tech. Rept. 1. Massachusetts Inst. Technol., NP-3477, TIP-U-17357, 1949, 14 pp.; Jour. Metals, vol. 1, No. 10, 1949, pp. 749-751.

A study of the structure of the borides of columbium, tantalum, titanium, vanadium, and zirconium. These compounds were found to correspond to the formula $MeB_2$ and have isomorphous crystal structure; the metal atoms were arranged in a simple hexagonal lattice having an axial ratio slightly greater than unity. The unit cell was found to contain one molecule of $MeB_2$, corresponding to the alternate layers of metal and B atoms, parallel to the basal plane of the lattice. All the borides were found to have well-developed metallic properties (TID-3010).

600. NORTON, F. H., KINGERY, W. D., ECONOMOS, G., AND HUMENIK, M., JR. Study of Metal-Ceramic Interactions at Elevated Temperatures. Massachusetts Inst. Technol., NYO-3144, Feb. 1, 1953, 83 pp.

Discusses factors affecting fabrication and properties; experimental methods, results, and analysis of results for interfacial reactions; and wetting properties, surface energies, and interfacial effects of metal-oxide combinations.

601. NORTON, F. H., KINGERY, W. D., FELLOWS, D. M., ADAMS, M., McQUARRIE, M. C., AND COBLE, R. L. Progress Rept. July 1-Sept. 30, 1950. Massachusetts Inst. Technol., NYO-596, 9 pp.

Conductivities of magnesia and stabilized zirconia specimens have been determined. Two independent runs were made on each specimen. Standard porosity measurements were made. Thin sections were prepared in the usual manner. Tables of conductivity values are included for each run.

602. NORTON, J. T., AND MOWRY, A. L. Solubility Relationships in Some of the Ternary Systems of Refractory Monocarbides. Jour. Metals, vol. 3, October 1951, pp. 923-925.

Examined isothermal sections of the pseudoternary carbide systems TiC-VC-ZrC, TaC-VC-ZrC, and NbC-VC-ZrC. The sections contain an inverted U-shaped, 2-phase field with a maximum extent of 77 molecular percent for TiC, 64 percent for TaC, and 51 percent for NbC. Isoparametric lines were determined, which show the curvature of the single-phase field and the direction of tie lines in the two-phase field. It was not possible to show any relationship between atom size and the extent of the two-phase field.

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ODELL, F. See abs. 228, 229, 230, 231.

603. OFFENHAUER, C. M., AND COLLINS, J. F. Effects of Zirconium in Cast Iron. Canadian Min. Met. Bull., vol. 42, July 1949, pp. 338-350.

A 750-pound ladle of metal from an all-pig charge was treated with 0.5 percent magnesium and 0.50 percent zirconium as magnesium-zirconium-silicon briquets added to the ladle just after the bottom had been covered with molten iron. The addition dissolved rapidly with no metal ejection from the ladle. The iron was poured into 40-pound hand ladles and inoculated with 0.40 percent silicon as "SMZ" alloy containing silicon 60 to 65 percent, manganese 5 to 7 percent, and zirconium 5 to 7 percent. Test castings were poured over an 8-minute interval. Tensile tests and microexamination indicated that zirconium additions were of value in producing strong, ductile cast iron. The zirconium addition was helpful in introducing the magnesium, reducing chill, and extending available pouring time. The effective addition was 0.50 percent zirconium and 0.50 percent magnesium followed by an inoculating addition of about 0.40 percent silicon and SMZ alloy. Tensile strengths from 6 to 9 x $10^4$ p.s.i. were obtained in combination with 6-percent elongation, and these properties could be modified by heat treatment. The hazards associated with the addition of metallic magnesium were reduced by pelleting fine magnesium with silicon-zirconium (TID-3010).

604. **OFFICE OF NAVAL RESEARCH (LONDON).** Physical Chemistry Research at the University of Vienna. ONRL-42-50, Apr. 5, 1950, 6 pp.

Brief summaries of the various projects in physical-chemistry research being conducted at the University of Vienna. One project was a study in the field of radiochemistry. The use of nuclear-emulsion photographic plates provides a highly sensitive method for the determination of upper limits of possible alpha activity. Although the general trend of the mass defect curve has suggested for some time that many heavy nuclei are unstable against alpha decay, the slowness of such decays and the low abundance of most of the alpha active nuclear species are difficult. A technique using photographic plates in which the full length of the alpha-ray tracks in the emulsion can be assured so that the possibility of confusion with other radioactive contaminants (polonium and others) is excluded and the effective layer thickness of the material under investigation is zero. The plates are impregnated with various ions by bathing them in suitable solutions for 30 minutes. After rinsing and drying they are stored for a long period up to 7 months and developed. Known radioactive materials are used as standard substances of comparison. The elements so far studied and the half lives (in years) of their alpha activities are as follows: Ag, Br $> 10^{18}$, Mo $> 9 \times 10^{15}$, Rb $> 17 \times 10^{15}$, Zr $> 2 \times 10^{15}$, Cd $> 6 \times 10^{15}$, Pb $> 3 \times 10^{15}$, Bi $> 3 \times 10^{15}$. Neodymium, praesydmium, and samarium have half lifetimes of about $2.6 \times 10^{14}$, $1.3 \times 10^{14}$, and $1.2 \times 10^{14}$, if they are alpha active at all.

**OGAWA, H.** See abs. 387.

605. **OKAZAKI, A., DARDEN, S. E., AND WALTON, R. B.** Total Cross Sections of Rare Earths for Fast Neutrons. Phys. Rev., vol. 93, No. 3, Feb. 1, 1954, pp. 461-463.

The total neutron cross sections averaged over resonances have been measured for neodymium, samarium, erbium, ytterbium, and hafnium as functions of neutron energy from 0.06 to 3 Mev. The cross-section curves have shapes that change gradually with atomic weight and are in agreement with the values predicted by the theory of Feshbach, Porter, and Weisskopf.

606. **OLSON, E. C., AND ELVING, P. J.** Amperometric Titration of Zirconium: Application to Fluoride Solution. Anal. Chem., vol. 26, No. 11, November 1954, pp. 1747-1750.

Although zirconium and its alloys are readily dissolved in hydrofluoric acid, the resulting solutions offer difficulties in the subsequent determination of zirconium. Accordingly, a method was sought for the direct determination of zirconium in the presence of excess fluoride ion. The amperometric titration of zirconium with cupferron in 2M sulfuric-acid solution was found to provide a satisfactory solution. The analytical precision is 0.4 percent or better. The method is subject to few interferences and may be applied without preliminary treatment to solutions containing zirconium in the presence of a 30- to 35-fold excess of fluoride ion without loss of accuracy; if aluminum is added, a much higher molar excess of fluoride can be tolerated. A gravimetric modification of the method may be used in solutions containing nearly a thousandfold excess of fluoride.

607. ORIANI, R. A., AND JONES, T. S. Apparatus for the Determination of the Solidus Temperatures of High-Melting Alloys. Rev. Sci. Instruments, vol. 25, No. 3, March 1954, pp. 248-250.

An apparatus has been developed for the determination of the melting temperatures of alloys up to 2,200° C., which attains blackbody conditions for the temperature measurements and precludes the possibility of contamination from a refractory container. Its operation has been checked by melting gold, nickel, iron, titanium, platinum, zirconium, and rhodium with an average reproducibility of ± 5° and an average deviation from the recognized melting points of 5° C. The melting point of pure vanadium has been determined as 1,919° ± 2° C.

OSBORN, G. H. See abs. 397.

OSBORNE, R. N. See abs. 375.

OVERHOLSER, L. G. See abs. 837.

608. OVERSTREET, R., AND JACOBSON, L. Preparation of Carrier-Free Zirconium and Niobium Tracers. (Ch. in Radiochem. Studies.) The Fission Products, Nat. Nuclear Energy Series, book 3, vol. 9, No. 6, (McGraw Hill Book Co., Inc., New York, N. Y., edited by C. D. Coryell and N. Sugarman), 1951, pp. 1517-1520.

A procedure for the simultaneous preparation of carrier-free zirconium and niobium activities from irradiated uranyl nitrate. The procedure makes use of the carrying of zirconium and niobium on thorium iodate to isolate these elements from most of the other fission products. The separation of niobium from zirconium is based on the formation of a soluble complex oxide of niobium by $K_2CO_3$ fusion.

OVERSTREET, R. See abs. 391, 773.

P

PAASCHE, O. G. See abs. 345.

PADWAL, N. A. See abs. 639.

609. PALACHE, C., AND ELLSWORTH, H. V. Zircon from North Burgess, Ontario. Am. Mineral., vol. 13, 1928, pp. 384-391.

Zircon crystals from North Burgess, Ontario, are characterized by unusual brilliance; by extraordinary constancy of angles, corresponding faces on any one crystal never varying in position by more than one minute; by larger angles than hitherto recorded for the species, the polar angles of all forms being from 5 to 6 minutes larger than the accepted values; these angles lead to an axial ratio of $\alpha$:c = 1:6429. The angles are increased by about 1 minute after heating to redness, a temperature which changes the red color to pure white. It is uniaxial, with the refractive indices of "normal zircon" and the indices are slightly lower after heating. The specific gravity 4.646-4.658 is increased by heating to 6.659-4.667. Analysis shows it to be very pure zirconium silicate with an inconsiderable content of hafnium.

PALEVSKY, H. See abs. 335.

PAPP, C. A. See abs. 513.

610. PARTRIDGE, J. H., AND LAIT, J. R. Manufacture of Refractory Articles From Pure Oxides of High Melting Point. Jour. Soc. Glass Technol., vol. 20, No. 80, August 1936, pp. 200-217.

Describes manufacture of crucibles, rods, and tubing from the pure refractory oxides $Al_2O_3$, MgO, BeO, $ThO_2$, and $ZrO_2$ and gives a general description of the production of highly refractory articles by fusion casting, slip casting, and the use of temporary bonding agents. Spacers of high electrical resistance for wireless valves are produced by molding $Al_2O_3$ and MgO under pressure, to tolerances of ± 0.5 percent. Wet-paste and slip-casting processes are employed for the production of crucibles. For the extrusion of rod or tubing, a plasticising agent of flour containing $NH_4OH$ is used for alumina and a cellulose composition for magnesia. The particle size must be graded to suit the diameter of the extruded shape. The extent of the firing shrinkage is controlled by particle-size grading, the ratio of plasticiser to material, and the use of material precalcined at different temperatures. Data are given on the chemical, thermal, and electrical properties of the materials produced.

**PATE, B. D.** See abs. 369.

611. **PATERSON, O. D.** Rare Metals: Their Production and Utilization. Australasian Eng., vol. 45, July 7, 1953, pp. 41-43.

A complete coverage of the rare metals from the standpoint of history, deposits, prospecting, mining, and future predictions as related to the Australian mining industry.

612. **PAULING, L.** Resonating-Valence-Bond Theory of Metals and Intermetallic Compounds. Proc. Roy. Soc. (London), vol. 196, series A, 1949, pp. 343-362.

The resonating-valence-bond theory of metals discussed differs from the older theory in making use of all nine stable outer orbitals of the transition metals, for occupancy by unshared electrons, and for use in bond formation; the number of valency electrons is consequently considered to be much larger for these metals than has been hitherto accepted. The metallic orbital, an extra orbital necessary for unsynchronized resonance of valence bonds, is considered to be the characteristic structural feature of a metal. It has been found possible to develop a system of metallic radii that permits a detailed discussion to be given of the observed interatomic distances of a metal in terms of its electronic structure. Some peculiar metallic structures can be understood by use of the postulate that the most simple fractional bond orders correspond to the most stable modes of resonance of bonds. The existence of Brillouin zones is compatible with the resonating-valence-bond theory and the new metallic valencies for metals, and alloys with filled-zone properties can be correlated with the electron numbers for important Brillouin polyhedra.

613. **PEARCE, J. N., AND RICE, M. J.** Adsorption of Water, Ethyl Alcohol, Ethyl Acetate and Acetic Acid Vapors by Tungstic and Zirconium Oxides, Its Bearing on Heterogeneous Catalysis. Jour. Phys. Chem., vol. 33, 1929, pp. 692-704.

The adsorption of water, ethyl alcohol, acetic acid, and ethyl acetate vapors by tungsten and zirconium oxides has been studied at 99.4°. The results obtained have been compared with those of a similar study of the adsorption of the same vapors by thoria and alumina. For unit volume of adsorbent, the adsorption capacities for water vapor decreases in the order $ThO_2$, $Al_2O_3$, $WO_3$, $ZrO_2$. This is also the order of the dehydrating power of these oxides toward alcohol. The order of adsorption for ethyl acetate is exactly the reverse of that for water vapor. The results confirm the view that in the catalytic process both the alcohol and acetic-acid vapors must be adsorbed simultaneously. Further, that the catalytic effect increases as the power of the oxide to adsorb water decreases.

**PEARSON, G. A.** See abs. 797.

614. **PENNEY, W. G., AND ANDERSON, J. S.** Note on Co-Ordination Numbers Eight.

Trans. Faraday Soc., vol. 33, 1937, pp. 1363-1368.

Eight elements (zirconium, molybdenum, ruthenium, cerium, hafnium, tungsten, osmium, and thorium) are known to form coordinated complexes with eight attached atoms. In 6 of the 8 elements the complex has a characteristic group of 24-valency electrons. The two exceptions are molybdenum and tungsten, which form complexes with groups of 25 or 26 valency electrons. These facts are shown to be predictable from the theory of molecular orbitals.

PENNING, F. M. See abs. 408.

615. PENNING, F. M., AND MOUBIS, J. H. A. On the Normal Cathode Fall in Neon. Physica, vcl. 15, Nos. 8-9, September 1949, pp. 721-732.

Applying the same method that had furnished reproducible results for molybdenum, the normal cathode fall $V_n$ in neon has been determined for a number of other materials (plate cathode, 40 mm. pressure). The results are given. The values of $V_n$ are compared with those those of the work function $\varphi$, and large deviations have been found from the relation $V_n = C\ \varphi$ (C a constant).

PEPINSKY, R. See abs. 726.

616. PERRYMAN, E. C. W., AND GOODWIN, R. J. Effect of Zirconium and Titanium on the Intercrystalline-Cracking Tendency of Beta-Brasses. Jour. Inst. Metals, vol. 83, No. 8, April 1955, pp. 378-382.

Solute elements of unfavorable size factor tend to form equilibrium segregates at grain boundaries. If the solute element is of high melting point, it is unlikely to diffuse readily in the solvent and should accordingly increase the effective viscosity of the grain boundaries. The addition to beta-brasses of suitably chosen elements of high melting point might, on these simple grounds, be expected to increase the resistance of the grain boundaries to the relaxation of shear stress and thereby decrease the liability of these materials to intergranular fracture. Small additions of zirconium and titanium were made to beta-brasses of three compositions. Impact and sustained tensile tests revealed improvement in the properties of two of them.

PETERSON, R. E. See abs. 88.

617. PETERSON, W. M. Zircon and Its Foundry Applications. Foundry, vol. 81, No. 4, April, 1953, pp. 92-95; Australasian Mfg., vol. 38, 1951, pp. 43, 44, 55, 56.

For certain applications, zircon is a most useful molding material because it combines high refractory value, heat conductivity, and density with low expansion and good resistance to being wetted by molten metal. The author describes how to make best use of these properties.

618. PHALNIKAR, C. A., AND BALDWIN, W. M., JR. Scaling of Zirconium in Air. ASTM, vol. 51, 1951, pp. 1038-1060; Case Inst. Technol., AECU-2763, (thesis), April 1951, 12 pp.

Both oxygen and nitrogen enter into the scaling reaction of zirconium in air. Given enough time zirconium forms a double-layered scale: An outer white or buff scale (monoclinic $ZrO_2$) that predominates at temperatures below 1,050° C. and an inner black scale (monoclinic and tetragonal $ZrO_2$, cubic ZrN, and possibly nitrogen), which occupies the greater thickness at temperatures above 1,050° C. An unusual feature is that the outer white layer does not form immediately but requires a definite time to nucleate. This time is as high as 100 hours near 400° C. and less than 5 minutes at 1,300° C. A second bizarre feature is reported: Zirconium strip undergoes extraordinary dimensional changes during scaling. Increases in dimensions in the rolling plane trebled the original sample area in some cases. This phenomenon did not set in immediately on heating but also required a definite time to commence. These times were, in general, much greater than those required to nucleate the outer white-scale layer, except in the temperature range 850° to 1,050° C. where the two times coincided. A Pilling and Bedworth parabolic relationhip between weight gain and time is roughly followed before the advent of the white outer scale. The appearance of the white scale layer increases the scaling rate enormously at low temperatures but not at high temperatures.

619. PHILLIPS, A. J. Partial Purification of Zirconium Oxide. Jour. Am. Ceram. Soc., vol. 1, 1918, pp. 791-800.

Zirconium oxide is a very desirable refractory for use at high temperatures, its high melting point as well as its low coefficient of expansion causing it to be very satisfactory with respect to checking and spalling upon rapid heating and cooling; likewise, its low thermal conductivity renders it very desirable as an insulating material. Several methods of decomposition of zircon are discussed with resulting reactions and analyses.

620. PHILLIPS, M. L. Visible Radiation Characteristics of Incandescent Oxides. Phys. Rev., vol. 32, November 1928, pp. 832-839.

Energy radiated in the visible part of the spectrum of various oxides and their mixtures when heated to red brightness temperatures between 1,400° and 2,000° K. by means of cathode-ray bombardment and gas-air and oxygas flames was measured by an optical pyrometric method. The oxides investigated were urania, ceria, lanthana, neodymia, erbia, yttria, zirconia, thoria, alumina, beryllia, magnesia, and mixtures of thoria with 1 percent ceria (the Welsbach mantle mixture), 1 percent and less of urania, 1 percent neodymia, and 1 percent manganese oxide. These were either pressed or fused to insure good surface conditions. Generally, linear relations were found between the logarithm of the red-blue intensity ratio and the reciprocal of the brightness temperature and between the logarithm of the candles emitted per unit surface area and the logarithm of the brightness temperature. Different modes of heating gave different radiation curves for the same oxide. Tables are given of the candles per square centimeter and the relative blue brightness for red-brightness temperatures of 1,400°-2,000° K.

621. PIDGEON, L. M. Production of Reactive Metals. Canadian Min. Met. Bull., vol. 43, September 1950, pp. 515-524.

Chemical-reduction and electrolysis production methods are discussed on a number of metals including zirconium.

622. PIETROKOWSKY, P. Intermediate Phase $Zr_2Si$. Acta Cryst., vol. 7, No. 5, May 20, 1954, pp. 435-438.

A zirconium-rich phase has been found in the binary system zirconium-silicon. The crystal structure of this intermediate phase, $Zr_2Si$, has been determined by powder X-ray diffraction methods. The unit cell, which is tetragonal, has parameters alpha = 6.6120 ± 0.0004 Å and c = 5.2943 ± 0.0003 Å. There are 8 zirconium atoms in (h) with X = 0.156 ± 0.001 and 4 silicon atoms in (alpha) of space group $D^{18}_{4h}$-14/mcm. Least squares methods methods were used to determine the lattice constants, position parameter, and errors associated with these measurements. $Zr_2Si$ is structurally isomorphous with $CuAl_2$(C16 type).

623. PIGOTT, E. C. Qualitative Chemical Tests for Iron, Steel and Foundry Materials. Iron and Steel (London), vol. 15, March 1942, pp. 196-199, 202.

Rapid methods of qualitative analysis for alloy irons and steels and other metals, including zirconium, are outlined. The necessary conditions attaching to purely inorganic methods are also given where required.

PLANKENHORN, W. J. See abs. 843.

PLEDGER, F. See abs. 105, 106.

PLOCK, L. F. See abs. 3.

624. **PLOTNIKOV, V. A., AND GITMAN, E. B.** (Electrodeposition of Zirconium). Jour. Appl. Chem. U. S. S. R., vol. 19, No. 8, 1946, pp. 826-832.

Search for a low-cost process of electrolytic production of coarse-grained zirconium in appreciable quantity and investigation of processes of separation of coarse powders of zirconium suitable for preparation of zirconium master alloys of various compositions for alloying purposes. Experimentation consisted of electrolysis of molten mixtures of aluminum and potassium chlorides, sodium fluoride, and zirconium dioxide; effect of temperature and cathode-current density; electrolysis in molten potassium fluoro-zirconate; electrolysis of mixture of potassium and sodium chlorides and potassium hexafluoro-zirconate; electrolysis of mixture of potassium and sodium chlorides, sodium fluoride, and zirconium dioxide; of molten mixture of zirconium tetrachloride and sodium chloride and decomposition potential of molten mixture.

625. **POLE, G. R., AND BEINLICH, A. W., JR.** New Refractory Compositions Resistant to Molten Rock Phosphate. Jour. Am. Ceram. Soc., vol. 26, 1943, pp. 21-37.

TVA has carried out studies during the past 5 years directed toward the development of refractories more resistant to corrosion by molten-rock phosphate than the present commercial types. Small-scale tests were made on refractories containing varying proportions of zirconium silicate and oxides of aluminum, beryllium, calcium, cerium, chromium, magnesium, thorium, and zirconium. Promising compositions were then tested by fabrication into standard 13-1/2-inch and 9-inch brick and by determining their resistance to corrosion by molten-rock phosphate, basic open-hearth slag, and electric phosphate-smelting furnace slag. The most promising of the compositions tested were (1) $Cr_2O_3$ 67 percent, CaO 30 percent, and $Al_2O_3$ 3 percent, and (2) $ZrO_2$ 33.5 percent, $Cr_2O_3$ 33.5 percent, CaO 30 percent, and $Al_2O_3$ 3 percent. A 25-kw. Detroit rocking furnace was lined successively with brick of these two compositions, as well as a commercial superduty firebrick and a commercial unburned magnesite brick, and each lining was tested against molten-rock phosphate until failure occurred. The tests show that the two new types of refractories are superior to the commercial refractories and that they may have promising possibilities for use where basic refractories are now extensively used.

POLLARD, F. H. See abs. 266.

626. **POMERANCE, H. S.** Some Isotopic Neutron Absorption Cross Sections. Oak Ridge Nat. Lab., AECD-2502, undated, decl. Feb. 18, 1949, 1 p.

The Oak Ridge pile oscillator was designed to measure thermal neutron-absorption cross sections of small samples. At present, macroscopic cross sections of 0.1 $mm.^2$ can be detected, and 1 $mm.^2$ can be measured with 10-percent accuracy. Many enriched isotopes produced at the Oak Ridge electromagnetic plant (Y-12) are available in sufficient weight to be used. The isotopes have been measured for four elements, and the weighted sum of the isotopic cross sections times their respective abundances have been compared with the cross sections for the normal element. The results on zirconium are: $Zr^{90}$ - 0.116 b, $Zr^{91}$ - 1.54 b, $Zr^{92}$ - 0.269 b, $Zr^{94}$ - 0.116 b, and $Zr^{96}$ 0.294 b. Estimated accuracies vary from 25 percent for the zirconium to 5 percent for the copper.

POOL, M. L. See abs. 468, 667.

627. **POOL, M. L., AND EDWARDS, J. E.** Radioactive Zirconium and Columbium. Phys. Rev., vol. 67, 1945, p. 60.

Extended observations on the decay of $Zr^{93}$ and $Cb^{93}$ show a genetical relationship between these two isotopes. $Zr^{93}$

is characterized by a half life of 67.8 days, a gamma ray of 0.85 Mev., a strong beta ray of 0.29 Mev., and a weak one of 0.8 Mev. The ratio of the intensities is approximately 8.

628. **POOLE, W. R.** Zircon and Rutile From Beach Black Sand Deposits. Chem. Eng. Min. Rev., vol. 31, Feb. 10, 1939, pp. 216-220; vol. 31, Mar. 10, 1939, pp. 250-257.

Extent, formation, and composition of the black-sand deposits of New South Wales.

**POREMBKA, S. W.** See abs. 685.

**POST, B.** See abs. 260, 289.

629. **POST, B., GLASER, F. W., AND MOSKOWITZ, D.** Transition Metal Diborides. Acta Met., vol. 2, No. 1, January 1954, pp. 20-25.

Structural characteristics of eight transition metal diborides, including zirconium, have been investigated. This paper discusses the structural and physical properties of these borides and their solid solutions.

**POSTEL, S.** See abs. 2.

**POTTS, A. M.** See abs. 2.

630. **POWELL, A. R.** Problems in the Production of Some of the Rarer Metals. (Ch. in Symposium on Refining Non-Ferrous Metals, 1949.) Inst. Min. and Met., London, 1950, pp. 51-72.

Describes the production of zirconium, utilizing electrolysis of fused chlorides, high-temperature reduction of chlorides, or oxides and thermal dissociation of the iodide.

See also abs. 699.

631. **POWELL, A. R., AND SCHOELLER, W. R.** Analysis of Brazilian Zirconium Ore. Analyst, vol. 44, No. 525, 1919, pp. 397-400.

Details of a method for analyzing Brazilian ores, which involves opening up the ore by fusion with sodium carbonate followed by a bisulfate treatment. The method is superior to the usual bisulfate fusion and is adaptable to the analysis of zirconium ores, zirconia, and zircon.

___. Investigations Into the Analytical Chemistry of Tantalum, Niobium, and Their Mineral Associates. XVIII. A New Method for the Separation of Titanium From Zirconium and Hafnium. See abs. 698.

**POWELL, A. R., SCHOELLER, W. R., AND JAHN, C.** Investigations Into the Analytical Chemistry of Tantalum, Niobium and Their Mineral Associates. XXIX. Separation of Tungsten From Titanium, Niobium, Tantalum, and Zirconium. See abs. 700.

632. **PRAKASH, S.** Cryotropic Behavior of Some Inorganic Jellies. Indian Jour. Phys., vol. 8, 1933, pp. 231-242.

Some of the jellies show a new sort of sol-gel transformation, which has been termed as cryotropy. Jellies like ferric phosphate and arsenate, aluminum and zirconium hydroxydes, and thorium molybdate and phosphate give rise to a sol when frozen in liquid air and again brought to the initial temperature. This sol is again converted to a gel after further standing. The process can be indefinitely repeated even with aged jellies. The jellies that have developed marked agglomeration tendency are noncryotropic. The conditions favoring cryotropy and its relation with thixotropy have been discussed.

633. ___. Influence of Temperature on the Setting of Inorganic Jellies. Jour. Indian Chem. Soc., vol. 9, 1932, pp. 193-202.

The influence of temperature on the setting of various inorganic jellies has been investigated. It has been observed that all the inorganic jellies set more readily at higher temperatures than at low. For such inorganic sols that do not undergo hydrolysis, the rise in temperature increases the rate of coagulation; consequently, hydration is more rapidly developed and the jellies are readily obtained. The jellies of polybasic salts are hydrolyzed at higher temperatures to the corresponding hydroxides, which have also a tendency to form jellies, and hence the setting time would depend upon the tendency of mixed phases. The jellies of vanadium pentoxide and thorium arsenate show the "melting phenomenon" at higher temperatures.

634. PRAKASH, S. Magnetic Study of Sols and Gels. Part I. Indian Jour. Phys., vol. 8, 1933, pp. 243-258.

In preliminary investigations the magnetic susceptibilities of various colloidal systems have been determined. A study has also been made of the magnetic susceptibilities of sols and gels of ferric phosphate, aluminum hydroxide, and zirconium hydroxide. No marked change is observed in the susceptibility of ferric phosphate sol when converted to a gel. However, the opalescent gels of aluminum and zirconium hydroxides show an increased diamagnetic value on aging.

635. ___. Preparation and Properties of Zirconium Sulfo-Salicylic Acid Jellies. Jour. Indian Chem. Soc., vol. 10, 1933, pp. 281-285.

This report covers the preparation of jellies of zirconium sulfo-salicylic acid and conditions of the formation of this jelly.

636. PRAKASH, S., AND DHAR, N. R. Influence of the Concentration of Coagulating Electrolyte, Time, and Temperature on the Syneresis of Some Inorganic Jellies. Jour. Indian Chem. Soc., vol. 7, 1930, pp. 417-434.

Results of a study on the influences of the concentration of the coagulating electrolytes, of time and temperature on the syneresis of zirconium hydroxide and zirconium borate.

637. ___. Preparation and Study of Some Hydroxide Jellies. Jour. Indian Chem. Soc., vol. 7, 1930, pp. 591-606.

Details of an investigation of the conditions of formation of ferric hydroxide, chromium hydroxide, aluminum hydroxide, stannic hydroxide, and zirconium hydroxide.

638. ___. Preparation of Borate, Tungstate, Molybdate and Other Jellies and Study of Mercurisulfosalicylic Acid Jellies. Jour. Indian Chem. Soc., vol. 7, 1930, pp. 367-378.

Methods of preparation of a number of jellies including zirconium borate.

639. PRASAD, M., GURUSWAMY, S., AND PADWAL, N. A. Opacity Changes During the Coagulation of Sols by Electrolytes. Proc. Indian Acad. Sci., vol. 19, 1944, pp. 389-400.

An apparatus for the measurement of opacity of gel-forming systems, was designed for use in the study of kinetics of coagulation of sols by electrolytes. The effects of temperature and the addition of nonelectrolytes on the coagulation were also examined. The sols employed were those of thorium, stannic, and zirconium hydroxides; the coagulation of these have been studied, and the results are discussed in this report.

640. PRASAD, M., AND MODAK, K. V. Viscosity Measurements During the Coagulation and Gelation of Concentrated Sols of Zirconium and Stannic Hydroxides. Proc. Indian Acad. Sci., vol. 15A, 1942, pp. 445-455.

Many complicated curves showing the relation between viscosity as determined in a capillary viscometer and time during coagulation and gelation of $Zr(OH)_4$ and $Sn(OH)_4$ solutions. (C.A.).

641. PRAY, H. A., MILLER, P. D., AND JEFFERYS, R. A. Chemical Surface Treatment of Titanium. Interim Technical Report. Battelle Mem. Inst., W.A.L.-401/45-26, May 30, 1953, 41 pp.

An extensive survey of chemical treatments of titanium and its alloys has produced two immersion treatments that offer useful and practical coatings on titanium alloys. These coatings, when subjected to a low-temperature thermal treatment, possess additional properties of war resistance, which reduce the galling tendency of titanium. The most notable aspect of this treatment is the production of a wear-resistant surface without change in the core properties of the titanium metal produced in treatments such as carburizing or nitriding. The commercial advantages of the coatings have been recognized by various industrial organizations dealing with titanium or its alloys.

PRESTWOOD, R. J. See abs. 130.

PUGH, S. F. See abs. 291.

642. PURUSHOTTAM, A., AND RAO, S. V. R. Tannin as a Reagent for Zirconium. Rec. trav. chim., vol. 70, 1951, pp. 555-558.

The use of tannin in separating zirconium from other elements has been investigated. With the exception of tin and titanium almost all elements commonly associated with zirconium may be separated in a single or a double precipitation in 0.1 N to 0.15 N-Hydrochloric acid solution. It is shown further that tannin gives a definite turbidity with as little as 0.002 mg. of $ZrO_2$ per ml. and quantities of 0.6 mg. and over may be conveniently estimated with the reagent.

643. ___. Use of Tannin in the Estimation of Zirconium and Its Separation From Thorium. Analyst, vol. 75, October 1950, pp. 555-557.

Zirconium is quantitatively precipitated by tannin from a chloride solution up to 0.15 N in hydrochloric acid. By double precipitation at this acidity it can be quantitatively separated from thorium.

## R

644. RADIATION LABORATORY, UNIVERSITY OF CALIFORNIA. Medical and Health Divisions Quart. Rept., October-December 1949, UCRL-587, Jan. 26, 1950, 53 pp.

Prompt treatment with zirconium citrate or sodium citrate appears not to have any significant effect upon the distribution and excretion of intravenously injected $Nb^{95}$. Zirconium citrate markedly decreased the skeletal deposition and increased the urinary excretion of plutonium. Sodium citrate increased the liver plutonium but had no sifnificant effect on either the skeletal deposition or urinary excretion. Prompt treatment with zirconium citrate appears to have definite value for the decontamination of internally administered plutonium but appears to have no effect on $Nb^{95}$ (TID-3010).

645. RAFTER, T. A. Sodium Peroxide Decomposition of Minerals in Platinum Vessels. Analyst, vol. 75, 1950, pp. 485-492.

Minerals that are resistant to decomposition by the usual methods can be decomposed easily and completely at comparatively low temperatures by means of sodium peroxide without the slightest attack on platinum vessels and with insignificant attack on iron or nickel vessels. Thermal analyses and gas-evolution experiments were made with several minerals as a preliminary to a more detailed study of the mechanism of peroxide decomposition.

646. RAIT, J. R., AND GREEN, A. T. Study of the Reactions Between Dolomite and Various Minerals. Part I. Constitution of the Fired Clinkers. Iron and Steel Inst., 1942, pp. 13-47.

Molded mixtures in various proportions of dolomite with flint, steatite, bentonite, china clay, olivine, serpentine, open-hearth slag, alumina, ferric oxide, zircon, baddeleyite, zirconia, rutile, chromite, and chromium oxide have been fired at about 1,500° C. Qualitative tests for the presence of free lime in the fired clinkers have been made, and quantitative determinations carried out on numerous samples. Measurements have also been made of the index of hydration of the clinkers. From a consideration of the relevant phase rule diagrams, assuming that the reactions in the clinkers had proceeded to equilibrium, the probable constitutions of the fired mixtures were calculated. The results of these calculations have been substantiated by (1) comparison of the calculated and experimentally determined free-lime contents; (2) the dusting of those clinkers, which calculation indicated contained a high percentage of calcium orthosilicate, and (3) by the form of the curves obtained on plotting the steam-hydration indices against the percentage of acidic oxides. In all the clinkers it was assumed that the magnesia was present uncombined as periclase. With increasing addition of silica or siliceous minerals, evidence indicated the increasing combination of the lime to form, first, tricalcium silicate, and, with larger silica contents, dicalcium silicate. There was evidence of the formation of $CaO.ZrO_2$ when zirconium minerals were added and of $2CaO.Cr_2O_3$ with chrome minerals.

647. **RAIT, J. R., AND GOLDSCHMIDT, H. J.** Study of the Reactions Between Dolomite and Various Minerals. Part IV. X-Ray Examination of the Sinters Containing Zirconia. Iron and Steel Inst., 1942, pp. 91-99.

Specimens of fired mixtures of dolomite with various proportions of zirconia, synthetic zircon, natural zircon, and baddeleyite have been submitted to X-ray analysis by the Deby-Scherrer powder method. From the photographs obtained, conclusions regarding the constitutions of the sinters have been made that substantiate those made previously on the basis of determinations of uncombined lime, steam-hydration indices, and from a consideration of the available thermal equilibrium data. It is confirmed that calcium metazirconate is formed by reaction of zirconia or zircon with the lime. Magnesia remains uncombined as periclase.

648. **RALSTON, O. C.** Zirconium Ores. (Ch. in Zirconium and Zirconium Alloys.) Am. Soc. Metals, Cleveland Ohio, 1953, pp. 1-4.

The principal commercial minerals of zirconium are zircon and baddeleyite, the former by far the most frequently used. The most easily worked deposits are beaches or stream channels. The supply in this form has not been well explored beyond the point of determining that an abundant supply for many years to come exists within the continental United States. Methods of concentration and separation from other dense minerals are listed and discussed.

649. **RANE, M. B., AND KONDIAH, K.** Note on the Vanadates of Heavy Metals. Jour. Indian Chem. Soc., vol. 8, 1931, pp. 289-292.

Describes the isolation, preparation, and composition of vanadates of mercury, gold, thorium, cerium, and zirconium.

650. **RAO, D. A. A. S. N.** Dielectric Constants of Crystals. Proc. Indian Acad. Sci., No. 30-A, 1949, pp. 82-86.

The dielectric constants of 15 crystals, including zircon belonging to different systems, are determined and reported together with previous values. Some of the values are found to be different from those reported by earlier investigators. Different specimens of tourmaline are found to have widely different dielectric constants. Corundum is found to have a higher dielectric constant in the direction of smaller refractive index.

**RAO, K. R.** See abs. 651.

**RAO, S. V. R.** See abs. 642, 643, 792.

651. **RAO, V. R., AND RAO, K. R.** Multiplet Separations in Complex Spectra

(of $d^3$ and $d^4$ Configurations). Indian Jour. Phys., vol. 22, 1948, pp. 175-179.

Expressions for multiplet separations derived by Goudsmit for complex spectra arising out of equivalent electron configuration have been applied to the spectra of vanadium and columbium, which have been recently analyzed extensively on the basis of Zeeman effect and hyperfine structure studies. The checkup between theoretical and experimental values have indicated a correspondence chiefly in the case of the deeper terms. The disagreement in columbium II is exceptionally large. Also given are the observed and calculated multiplet separations in zirconium II, for which the ground configuration corresponds to $d^3$.

RAU, W. J. See abs. 755.

652. **RAYNOR, W. M.** Some Aspects of the Iodide, or Hot Wire, Process for Manufacture of Zirconium. (Ch. in Zirconium and Zirconium Alloys.) Am. Soc. Metals, Cleveland, Ohio, 1953, pp. 73-81.

In the refining of zirconium by the iodide process in a closed system it was found that deposition rates were very sensitive to changes in operating conditions, such as filament temperature, iodine content, and vessel temperature. The work described in this paper was undertaken in an effort to determine the rate-limiting factors and the optimum operating conditions to permit maximum production in the specific type of equipment employed.

653. **REED, E. L.** Stability of Refracries in Liquid Metals. Jour. Am. Ceram. Soc., vol. 37, No. 3, March 1954, pp. 146-153.

Present technological developments are making more extensive use of liquid metals as heat-transfer agents. Their stable and relatively noncorrosive character makes them especially adaptable for high-temperature applications. The compatibility of various liquid metals with refractories has been investigated in the past over a temperature range up to several hundred degrees centigrade. To extend this information to much higher temperatures, corrosion experiments were carried out at North American Aviation, utilizing liquid sodium, tin, and bismuth. Tests were conducted in the range 800° to 1,500° C., using molybdenum, tantalum, tungsten, graphite, alumina, zirconia, and other materials. The experimental apparatus and procedures employed in conducting both static and dynamic tests are described, and significant results are summarized.

REES, A. L. G. See abs. 330, 523.

654. **REES, W. J., AND CHESTERS, J. H.** Preliminary Investigation of the Magnesia-Zircon Series. Trans. Ceram. Soc. (England), vol. 29, 1930, pp. 309-316.

A preliminary investigation of the properties of the magnesia-zircon series and the results explained by assuming maximum melt formation for a (20-80) mixture and the maximum formation of a mineral of lower density for a (50-50) mixture. The formation of such a mineral has been confirmed by X-ray and microscopic work. It is suggested that this mineral is probably a magnesium-zirconium silicate. Some of the properties of the refractory compensated mixture are also discussed.

REID, E. E. See abs. 118.

REINERS, C. R. See abs. 62, 63, 64.

655. **REMMEY, G. B.** Upper Useful Limits of Commercial Superrefractories. Am. Ceram. Soc. Bull., vol. 27, No. 12, Dec. 15, 1948, pp. 477-485.

Eighteen different brands of fabricated mullite and alumina refractories, as well as 1 zircon and 1 zirconia brick, were tested to determine their upper limits of use. Reheat tests were run for 4 hours at temperatures held constant at 6 values ranging from 3,000° to 3,500° F. from which the shrinkage effects on each sample were calculated. Pyrometric cone equivalent and load tests were also made. In addition to the test results, the methods are outlined as a suggested procedure for evaluating such superrefractories. Data are also given on the temperatures at which zircon and zirconia react with mullite and alumina. The extremely fluid nature of the glasses formed at 3,350° F. and above is illustrated.

656. RENTSCHLER, H. C., AND HENRY, D. E. Effect of Oxygen Upon the Photoelectric Thresholds of Metals. Jour. Opt. Soc. Am., vol. 26, January 1936, pp. 30-34.

When a small amount of oxygen is allowed to react with an active surface of certain metals such as thorium, uranium, calcium, barium, and caesium, the photoelectric threshold is shifted toward the longer wavelength. A similar reaction of oxygen with other metals such as titanium, zirconium, silver, iron, nickel, etc., shifts the threshold toward shorter wavelength; oxygen produces no effect on gold. The photoelectric work functions obtained for the oxygen-treated surfaces of thorium, uranium, and calcium agree with the thermionic work functions of tungsten filaments containing oxides of these metals when activated. The experimental results indicate that the effects from these oxygen-treated surfaces are due to the activity of the product of the interaction of oxygen with the metal and not due to a single atom layer of the metal on a base material.

657. RENTSCHLER, H. C., HENRY, D. E., AND LILLIENDAHL, W. C. Zirconium and Thorium Electrodes in Discharge Lamps. Trans. Electrochem. Soc., vol. 91, 1947, pp. 299-308.

Describes experiments indicating that blackening of the glass in bactericidal ultraviolet lamps is due to the interaction of oxygen with mercury. The substitution of special Vycor for the ultraviolet transmitting glass now in common use increases the initial output and reduces the deterioration caused by solarization and virtually eliminates the objectionable generation of ozone. Stability of the discharge is greatly improved by the use of zirconium or titanium electrodes. Zirconium and thorium electrodes in special lamps in Vycor can be used for testing the stability of fluorescent powders.

RICE, M. J. See abs. 613.

RICH, M. N. See abs. 518.

658. RICHARDSON, D. Boiling-Point Determinations by Spectroscopic Methods. (Ch. in Proc. of the Fifth Summer Conference on Spectroscopy and Its Applications.) Technol. Press, Massachusetts Inst. Technol. (John Wiley & Sons., Inc., New York, N. Y.), 1938, pp. 64-70.

Boiling-point determinations of zirconium were done on a quartz prism spectrograph. The method used is outlined and the boiling-point data are tabulated.

659. RICHARDSON, H. M., CLEWS, F. H., AND GREEN, A. T. Experiments on the Action of Chlorine on Certain Oxides, Silicates and Spinels. Trans. British Ceram. Soc., vol. 41, 1942, pp. 196-205.

The conversion of various oxides into chlorides by the action of chlorine at 1,000° C. has been studied. The following is the approximate order of reactivity: Iron oxide > magnesia > lime > titanium dioxide > zirconia > alumina > silica. More complex compounds containing these oxides, such as various silicates and spinels, were less reactive than the free constituent oxides. The rate of reaction was dependent on the previous thermal history of the samples, being less for materials for which had been strongly calcined.

660. RICHARDSON, R. S. Investigation of Molecular Spectra in Sun-Spots. Astrophys. Jour., vol. 73, 1931, pp. 216-249.

The results of an investigation of molecular spectra in sunspots, especially in the region λ 4500 to λ 5500, and the presence of $ZrO_2$.

RICHTER, J. W. See abs. 704.

RICHTMYER, F. K. See abs. 361.

661. ROACH, J. D. Zirconium. Chem. Eng., vol. 60, No. 9, September 1953, pp. 304, 306, 308.

Discusses corrosion resistance of zirconium to a number of corrosives, with physical properties, forms available, and applications.

662. ___. Zirconium. Machine Design, vol. 26, No. 5, May 1954, pp. 156-158.

Data on the methods of producing zirconium, properties and production characteristics, uses, and economics.

663. ROAKE, W. E. Preparation of Carrier-Free Radiozirconium From Pile-Irradiated Uranium. Hanford Works, AECD-3201, 1951, decl. June 11, 1951, 8 pp.

The unique radiocolloidal behavior of zirconium and its daughter niobium (columbium) may be used to separate, by simple adsorption, carrier-free zirconium and niobium from fission products. Relative adsorption capacities and the effects of temperature and pH on adsorption are tabulated. The following detailed method is given: Zirconium and niobium are removed from a 1.5M nitrate solution of pile-irradiated uranium by adsorption on Super-Filtrol during one hour heating to 100° C. The Filtrol cake is filtered and washed clean of supernatant with 0.01M $HNO_3$ and leached with 10M $HNO_3$ for 30 minutes at 100° C. The resulting solution of carrier-free zirconium is freed from daughter niobium by an extraction cycle with 0.01M thenoyltrifluoroacetone (TTA) in benzene (TID-3010).

ROBERSON, A. H. See abs. 18, 345.

664. ROBERTS, J. S., III. Precipitation Age Hardening of Copper-Zirconium Alloys. Rensselaer Polytechnic Inst. (Thesis), June 6, 1939, 26 pp.

The investigation was conducted to determine the physical properties of copper-nickel-zirconium and copper-silicon-zirconium alloys, subjected to precipitation age hardening by heat treatment and then reduced by cold work. The results showed that the maximum tensile strength and hardness of both alloys occurred at the maximum solubility of zirconium in copper.

665. ROBERTS, L. D., AND DABBS, J. W. T. Superconductivity of a Hafnium-Zirconium Alloy. (Ch. in Physics Div. Quart. Prog. Rept. for period ending Mar. 20, 1952.) Oak Ridge Nat. Lab., ORNL-1289, Oct. 22, 1952, pp. 19-20.

The magnetic susceptibility of a hafnium-zirconium alloy (about 10 atomic-percent zirconium) has been investigated in the liquid helium temperature region and below 1° K. by method a'' of Kürti and Simon (TID-3010).

666. ROBERTS, S. Polarizabilities of Ions in Perovskite-Type Crystals. Phys. Rev., vol. 81, No. 5, Mar. 1, 1951, pp. 865-868.

Each type of ion is shown to have very nearly the same polarizability in different crystals of the perovskite type as well as in the diagonal cubic types reported previously. This conclusion is based upon dielectric constant data for several titanates and zirconates and $KMgF_3$. The values of ionic polarizability are proportional to the cube of the radius for ions in the same valence series.

667. ROBERTSON, B. E., SCOTT, W. E., AND POOL, M. L. Radioactive $Y^{84}$, $Y^{88}$ and $Zr^{87}$. Phys. Rev., vol. 76, No. 11, Dec. 1, 1949, pp. 1649-1650.

A 3.7-hour activity, assigned to $Y^{84}$, has been obtained by bombardment of $Sr^{84}$ with 10-Mev. deuterons. Characteristic radiations are 2.0-Mev. positrons, X-rays and gamma rays. A 2.0-hour activity, assigned to $Zr^{87}$, has been obtained by bombarding natural strontium and $Sr^{84}$ with 20-Mev. alpha-particles. Characteristic radiations are 2.0-Mev. positrons, X-rays, and gamma-rays. Bombardments of $Sr^{87}$ + d, Y + $n^f$ and Rb + alpha are in agreement with the assignment of a 105-day activity to $Y^{88}$ but show no evidence of a 2.0-hour positron activity previously assigned to $Y^{88}$.

ROBINSON, D. W. See abs. 323, 324.

668. RODD, E. H. Zirconia as a Refractory. Jour. Soc. Chem. Ind., vol. 37, No. 11, June 15, 1918, pp. 213-215.

Deposits, properties, and uses of zirconia as a refractory.

669. RODGERS, J. W. Metallurgy of Titanium and Zirconium. (Ch. in The Metallurgy of the Rarer Metals.) Inst. of Metallurgists (London) May 1953, pp. 79-98.

Considers the properties of both titanium and zirconium and the methods used for their extraction from the ore.

RODRIGUES, A. A. See abs. 308.

670. ROGERS, B. A., AND ATKINS, D. F. Zirconium-Columbium Diagram. Ames. Lab., Iowa State Coll., ISC-500, June 29, 1954, 39 pp.

An account of an investigation of the zirconium-columbium alloy system, a brief review of the information available from previous publications, and a description of the apparatus and methods used in the new investigation. A relatively simple constitutional diagram is presented. Complete mutual solid solubility exists for an interval below the solidus line, which is a continuous curve with a flat minimum near 22 percent columbium and 1,740° C. Upon cooling, the solid solution breaks up, except at the columbium-rich side, from two causes. Zirconium-rich alloys transform under the influence of the beta-alpha transformation in zirconium; alloys of intermediate composition decompose into two solid solutions below 1,000° C. The combined effect is the formation of a eutectic at a temperature of 610° C. and a composition of 17.5 percent columbium. The eutectoid horizontal extends from 6.5 percent columbium to 87.0 percent columbium. Some age-hardening effects have been observed in the zirconium-rich alloys, but the positions of the solvus lines remain uncertain.

671. ROSTOKER, W., McPHERSON, D. J., AND HANSEN, M. Exploration of Vanadium-Base Alloys. Armour Research Found., WADC-TR-53-178, May 1953, 103 pp.

Describes the results of work performed during the period May 14, 1952, to May 14, 1953. The forgeability of a large number of binary alloys was investigated. While many proved forgeable, the room temperature ductilities of all but vanadium-titanium and vanadium-zirconium alloys were poor. Ternary alloys based on vanadium-titanium were investigated. Elevated-temperature tensile properties have shown much promise. Studies on improvement of the oxidation characteristics of vanadium alloys have proved fruitful; chromium and aluminum additions were found to be particularly effective. A number of alloys have demonstrated sufficient resistance for 100 hours at 700° C. Limited studies were conducted on the systems vanadium-oxygen and vanadium-nitrogen.

ROTH, R. S. See abs. 164.

672. ROTHMAN, A., McKINNEY, D. S., AND WARNER, J. C. Progress Report for June 1951. Carnegie Inst. Technol., NYO-548, Jan. 3, 1952, 8 pp.

Experiments have been carried out to determine the effects of various salts and complexing agents on the anodic overvoltage of titanium and zirconium in 2.06 N $H_2SO_4$ at a current density of 20 microamperes per square centimeter. The salts tested are from a list of salts that caused titanium to corrode at a rate greater than 0.005 inches per year. In the observation of two cases in the plots of e.m.f. versus time, there was either a sudden drop in overvoltage, a change in the overvoltage of the zirconium anode in the cathodic direction, or there was only a slight overvoltage change due to a concentration polarization effect.

673. ROTHSTEIN, A. Toxicology of the Minor Metals. Univ. Rochester, UR-262, June 5, 1953, 34 pp.

Pharmacology and toxicology of the minor metals and their compounds. Included in the discussion are the following: Aluminum, cadmium, cobalt, copper, germanium, gold, manganese, nickel, platinum, selenium, silver, tellurium, thallium, uranium, vanadium, zinc, and zirconium.

674. ROY, S. B. Factors Affecting the Properties of Typical Zircon Porcelain. Part I. Jour. Sci. Ind. Res., vol. 9B, 1950, pp. 253-258.

A survey of the different methods of incorporating the alkaline earth fluxes in typical zircon porcelain compositions.

675. ROZSA, J. T. Spectrochemical Techniques Advance Titanium Technology. Iron Age, vol. 172, Sept. 17, 1953, pp. 166-170.

Recent development of production methods for titanium has stirred a keener interest in analytical control methods. Use of the emission spectrograph, aided by improved techniques for producing standard samples, overcomes previous difficulties and meets the analytical requirements for this new metal. Applied successfully to the development of beryllium, zirconium, and uranium, this method of analysis provides the necessary flexibility, precision, and speed.

RUBIN, T. See abs. 12.

RUNDLE, R. E. See abs. 43.

676. RUNDLE, R. E., SHULL, C. G., AND WOLLAN, E. O. Crystal Structure of Thorium and Zirconium Dihydrides by X-ray and Neutron Diffraction. Ames Lab., Iowa State Coll., AECU-1275, Apr. 20, 1951, 18 pp.; Acta Cryst., vol. 5, 1952, pp. 22-26.

Thorium forms a tetragonal lower hydride of composition $ThH_2$. The hydrides $ThH_2$, $ThD_2$, and $ZrD_2$ have been studied by neutron diffraction so that hydrogen positions could be determined. The hydrides are isomorphous and have a deformed fluorite structure. Metal-hydrogen distances in thorium hydride are unusually large, as in $UH_3$. Thorium and zirconium scattering amplitudes and a revised scattering amplitude for deuterium are reported.

677. RUSSELL, D. S. Determination of Oxygen and Magnesium in Zirconium Metal. Chem. in Canada, vol. 6, No. 5, May 1954, p. 38.

An abstract on a volitalization method in which the metallic zirconium is removed by volatilization as the zirconium tetrachloride to leave a residue of unreacted zirconium oxide.

678. RUSSELL, R. B. On the Zirconium-Hafnium System. Jour. Appl. Phys., vol. 24, No. 2, February 1953, pp. 232-233.

The author confirms Duwez' transformation temperature of the zirconium-hafnium system at 94 atom-percent hafnium. The author reconciles a discrepancy in composition found by Fast by showing that different units were used in determining the lattice parameters and by a probable positive Vegard deviation that increases the effect of small amounts of zirconium on the lattice parameters.

679. RUSSI, R. F., JR., AND WILHELM, H. A. Constitution Diagram of the Antimony-Zirconium Alloy System.

Ames Lab., Iowa State Coll., AECD-3610, August 1951, 42 pp.

Antimony-zirconium alloys were prepared by diluting a master alloy of 23.6 weight-percent antimony with magnesium-free sponge zirconium. The master alloy was made by diffusing analytical grade antimony into sponge zirconium in a sealed stainless-steel container, at a temperature of about 825° C. These alloys were studied by microscopic examination of slow-cooled and quenched specimens. Thermal analysis and fusion temperatures as well as X-ray, corrosion, and hardness data were obtained.

680. **RUTGERS UNIVERSITY.** (N. J. Ceram. Res. Sta.) Prog. Rept. 2, Mar. 1 to June 1, 1951, 81 pp.

Calibrations of the high-vacuum thermal-conductivity apparatus, using lead, are reported. Tests include specimens of 0.500 and 0.405 inches in diameter. Good reproducibility is indicated. The thermal conductivity of eight specimens containing BeO, $Al_2O_3$, $ZrO_2$, $ThO_2$, $TiO_2$, MgO, CaO, and Rh from the National Bureau of Standards have been evaluated and are included in this report. The development of a low-zircon-type porcelain body, which is in pilot-plant stage, is given. This body possesses grade L4 electrical properties by JAN-I-10 specifications, high strength, good strength, good thermal shock properties and is relatively easy to fabricate.

681. **RUTHER, W. E., AND DRALEY, J. E.** Solution Potentials of Zirconium. Argonne Nat. Lab., ANL-5165, Dec. 25, 1953, 16 pp.

The solution potentials of zirconium crystal bars were measured at 50° C. and 315° C. in gas-saturated distilled water and in other aqueous solutions. An attempt was made to correlate these potentials with the previously observed corrosion behavior of the zirconium samples in water at 315° C. No correlation was observed for any of the tested solutions. The relation between the solution potential of zirconium and that of stainless steel was observed as a function of pH at 315° C. and as a function of temperature in neutral water.

**RYERSON, F. E.** See abs. 48.

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682. **SALLER, H. A.** Metals for Reactor-Core Construction. Science, vol. 119, Jan. 1, 1954, pp. 4-8.

Discusses developments in the field of materials suitable for reactor-core construction.

See also abs. 739.

683. **SALLER, H. A., DICKERSON, R. F., AND CARLSON, R. J.** Equipment for Metallographic Studies at Elevated Temperatures. Battelle Mem. Inst., BMI-X-114, Mar. 2, 1954, 13 pp.

A microscopic hot stage has been constructed, which makes possible the observation of structural changes in a metal at temperatures up to 1,800° F. The principal parts of the equipment are a vacuum furnace, an optical group, a cold trap, and a vacuum-pumping group. The structures of uranium, zirconium, and SAE-1008 steel at elevated temperatures have been photographed to illustrate the quality of work that can be accomplished with the equipment.

684. **SALLER, H. A., DICKERSON, R. F., AND FOSTER, E. L., JR.** Induction-Melted Zirconium and Zirconium Alloys. Battelle Mem. Inst., BMI-908, Mar. 18, 1954, 37 pp.

Two types of zirconium and three zirconium alloys have been induction melted and their properties determined. Sponge zirconium, iodide zirconium machine chips, Zircaloy 2 (zirconium-1/5 w/o tin-0.12 w/o iron-0.10 w/o chromium-0.05 w/o nickel), and zirconium alloys containing 2.5 and 5 w/o tin, respectively, were the specific materials investigated. Melting and fabrication techniques were studied, and data on hardness, electrical resistivity, corrosion behavior in 400° C.

steam and 200°, 260°, 290°, 315°, and 360° C. water, and the capacity of the metal to be drawn were accumulated. Of the materials tested, the iodide zirconium machine-chip metal was found to have the lowest electrical resistivity at all temperatures and should be the most amenable to drawing operations. Corrosion tests in water and steam indicated that Zircaloy 2 corroded at a slower rate than did the binary tin alloys and that cold working improved the corrosion properties of all the induction-melted materials. The tensile strengths of the metal are higher than the strengths of corresponding arc-melted materials, and these higher strengths are in part explained by the presence of an iron-rich grain-boundary phase in the induction-melted stock.

685. **SALLER, H. A., STACY, J. T., AND POREMBKA, S. W.** Strength of Wrought Zirconium-Base Binary Alloys at 1,800 to 2,200° F. Battelle Mem. Inst., BMI-903, Feb. 17, 1954, 22 pp.; Am. Soc. Metals, vol. 47, preprint 37, 1954, 14 pp.

The effects of a number of elements on the workability, hardness, and high-temperature strength of zirconium were investigated. Binary alloys of zirconium with chromium, columbium, molybdenum, tantalum, tungsten, and vanadium were surveyed. A short-time stress-rupture apparatus was constructed to determine strengths in a neutral atmosphere at 1,800 to 2,200° F. Alloys of tantalum or tungsten were the most easily worked, and those containing chromium or vanadium were the most difficult to work. At 1,600° F., maximum hardness was obtained with a tungsten addition. Tungsten also appears to be the most effective strengthener for zirconium at 1,800 to 2,200° F.; a zirconium-8 w/o tungsten alloy had a 100-hour creep-rupture strength of 1,700 p.s.i. at 1,800° F. None of the alloys studied were superior in strength to Inconel or type 310 stainless steel over the range 1,800° to 2,200° F.

**SAMSONOV, G. V.** See abs. 542.

686. **SAM TOUR AND CO., INC.** Research and Development of Methods of Chemical Analysis for Titanium Metal and Its Alloys. Interim Tech. Rept. NP-3745, Mar. 3, 1952, 73 pp.

Various methods of chemical analysis are discussed and evaluated for 12 elements in titanium metals and alloys. The mandelic method is used for the analysis of zirconium.

687. **SANDERSON, L.** Zirconium. Canadian Min. Jour., vol. 75, No. 3, March 1954, pp. 67-69.

A comprehensive review of zirconium, including data on its history, zircon, and baddeleyite, nuclear-energy uses, properties, industrial applications, and alloys.

688. **SANDSTROM, A.** Investigation Into X-ray Absorption Spectra. Nova Acta Regiae Soc. Sci. Upsaliensis, ser. IV, vol. 9, No. 11, 1935, pp. 1-92.

Describes a concave-crystal spectrograph with which it is possible to obtain spectrograms with an even distribution of the intensity without moving the spectrograph or part thereof. Some systematic errors are discussed. In connection with an earlier investigation shows that the $L_{III}$- and $L_{II}$-edges of the elements 40 Zr-46Pd represent transitions to the incomplete $N_{IV,\ V}$-level. In the same way the $L_{I}$-edge of the elements 48 Cd-52Te arises from transitions to the incomplete $O_{II,\ III}$-level. It seems to be a universal rule in X-ray absorption spectra that an absorption-transition always takes place to the first incomplete level, if such a transition is allowed by the selection rules. Hitherto, no traces of quadruple transitions have been found in X-ray absorption spectra.

**SARKAR, P. B.** See abs. 328.

689. **SATOH, S.** Specific Heats of Zirconium Nitride and Magnesium Nitride. Sci. Papers Inst. Phys. and Chem. Res., Tokyo, vol. 34, No. 774, 1938, pp. 399-405.

The specific heats of zirconium nitride and magnesium nitride have not yet been determined. The object of the present study is to determine the specific heats of both substances.

690. SAWAGUCHI, E. Lattice Constant of $PbZrO_3$. Jour. Phys. Soc. (Japan), vol. 7, No. 1, January, February 1952, pp. 110-111.

Brief report of an X-ray study of the temperature change of lattice parameters.

See also abs. 727, 728.

691. **SCADDEN, E. M., AND BALLOU, N. E.** Solvent Extraction Separations of Zirconium and Niobium. Anal. Chem., vol. 25, No. 11, November 1953, pp. 1602-1604.

The extraction characteristics of a variety of solvent systems have been examined for the purpose of finding a method for quickly and efficiently isolating zirconium and niobium from all other fission product elements. The mixed butyl phosphoric acids in di-n-butyl ether were found effective for this purpose. Conditions have been established for rapidly and efficiently separating both macro and carrier-free concentrations of these two elements from each other and from nearly all other fission product elements. Application of the solvent system to other separations is indicated. Conditions for simply separating the yttrium from the lanthanum-group rare earths have been found.

692. SCARLOTT, C. A. Zirconium - From Rarity to Reactors. Westinghouse Eng., vol. 13, No. 5, September 1953, pp. 171-173; ASTM Bull. 194, December 1953, pp. 45-46.

Story of the transit of zirconium from obscurity to production status.

SCHARFF-GOLDHABER, G. See abs. 300.

693. **SCHAWLOW, A. L., AND TOWNES, C. H.** Nuclear Magnetic Moments and Similarity Between Neutron and Proton States in the Nucleus. Phys. Rev., vol. 83, 1951, pp. 268-269.

Nuclear magnetic moments and some spins are predicted for the corresponding odd-neutron nuclei $Ne^{21}$, $Si^{29}$, $S^{35}$, $Ca^{43}$, $Ti^{47}$, $Ti^{49}$, $Cr^{53}$, $Fe^{57}$, $Ni^{61}$, $Ge^{73}$, and $Zr^{91}$.

694. **SCHELL, D. C., AND NEFF, J. M.** Refractory Oxide Bodies and Coatings for Aircraft Power Plants. Armour Res. Found., AF-TR-6081, June 1950, 12 pp.

Reviews progress on the development of refractory coatings for metal alloys by a novel method somewhat analogous to the process used by Corning Glass Works in the manufacture of Vycor high-silica glass. The research program has for its objective the coating of metals with glassy or semicrystalline enamels consisting essentially of alumina, titania, or zirconia.

SCHERB, M. V. See abs. 514, 515.

SCHLAIN, D. See abs. 298.

SCHLECHTON, A. W. See abs. 461, 462, 463.

695. SCHOELLER, W. R. Tannin as a Selective Reagent for Zirconium. Analyst, vol. 69, No. 822, September 1944, pp. 259-262.

Zirconium is quantitatively precipitated by tannin from chloride solution containing free hydrochloric acid below 0.1 N concentration. The reaction affords separation of zirconium from sesquioxides, monoxides, uranium, vanadium, and thorium, the bulk of the zirconium being first precipitated at 0.025 to 0.5 N acidity and the small balance in the filtrate by partial neutralization. Titanium and tin are precipitated with the zirconium. The advantages of tannin as a selective reagent for zirconium are discussed.

696. **SCHOELLER, W. R., AND WATERHOUSE, E. F.** Investigations Into the Analytical Chemistry of Tantalum, Niobium and Their Mineral Associates. XIII. A New Method for the Separation of Zirconium and Hafnium From Tantalum and Niobium. Analyst, vol. 53, No. 631, October 1928, pp. 515-520.

Describes a new method for separating small quantities of earth acids from large amounts of zirconia (hafnia). The process is based on the precipitation of the oxalo-earth acids by tannin in weakly acid solution, zirconyl oxalate remaining dissolved. The method described in an earlier report, fusion of the mixed oxides with potassium carbonates, has been perfected, with the result that a single fusion may separate the bulk of the earth acids. The remainder is then separated from the zirconia residue by the tannin procedure. This is a delicate test for detecting the smallest quantities of earth acids in zirconia.

697. **SCHOELLER, W. R.** Investigations Into the Analytical Chemistry of Tantalum, Niobium and Their Mineral Associates. XV. A New Method for the Separation of Tantalum and Niobium From Titanium and Zirconium (1: Qualitative). Analyst, vol. 54, 1929, pp. 453-460.

Describes a new process (the pyrosulfate and tannin method) for the qualitative separation of tantalum and niobium (columbium) from titanium and zirconium. It consists of fusing the mixed oxides with bisulfate and extracting the fusion product with 5 percent sulfuric acid containing 1 percent of tannin. The earth acids remain insoluble as colored tannin adsorption complexes, while the sulfates of titanium and zirconium dissolve. The addition of tannin prevents the formation of complexes, which render the separation ineffective when the bisulfate melt is leached with cold water or dilute acid.

698. **POWELL, A. R., AND SCHOELLER, W. R.** Investigations Into the Analytical Chemistry of Tantalum, Niobium and Their Mineral Associates. XVIII. A New Method for the Separation of Titanium From Zirconium and Hafnium. Analyst, vol. 55, No. 655, October 1930, pp. 605-612.

The present position of the titania-zirconia separation is reviewed, and the Dittrich and Freund salicylate method is being reinvestigated. The process did not lead to a clean-cut separation, as the zirconia residue from a double treatment still contained titania, and some zirconia accompanied the titania into the filtrates. A new method is explained, based upon precipitation of the titania by tannin from a neutralized oxalate solution half saturated with ammonium chloride; a repetition of the procedure results in the quantitative precipitation of the titania with only traces of zirconia, if any. The method is simpler and quicker than the published processes. A preliminary account is given of the extension of the new method to the separation of the earth acids or titania or both from any or all of the following: Zirconia, thoria, and alumina.

699. **SCHOELLER, W. R., AND POWELL, A. R.** Investigations Into the Analytical Chemistry of Tantalum, Niobium and Their Mineral Associates. XXIII. The Quantitative Separation of Tantalum, Niobium, Titanium and Zirconium and a New Analytical Grouping. Analyst, vol. 57, 1932, pp. 550-554.

A method for the separation of titanium from zirconium, based on precipitation of the titania as tannin complex from the nearly neutralized oxalate solution half saturated with ammonium chloride, affords a quantitative separation of tantalum, niobium, and titanium (acid tannin group) from zirconium, thorium, and aluminum (basic tannin group). Under the conditions realized by the procedure, tannin acts as a group reagent, precipitating any or all of the members of the acid tannin group and thus separating them from any or all members of the basic tannin group. The inclusion of certain other metals in the latter group is being investigated.

700. **POWELL, A. R., SCHOELLER, W. R., AND JAHN, C.** Investigations Into the Analytical Chemistry of Tantalum, Niobium and Their Mineral Associates. XXIX. Separation of Tungsten From Titanium, Niobium, Tantalum and Zirconium. Analyst, vol. 61, 1936, pp. 506-514.

The procedure to separate tungsten from titanium and niobium, with or without tantalum and zirconium, consists in fusing the mixed oxides with potassium carbonate and treating the aqueous extract of the melt with a slightly ammoniacal magnesium-salt solution; the earths are precipitated, and the alkali tungstate remains in solution. A repetition of the procedure is necessary unless the mixed earths contain a large proportion of niobic oxide; for accurate work, however, double treatment is recommended in all cases. Zirconia may be separated from tungstic oxide by fusion with alkali carbonate and extraction with water. The applicability of the methods available for the separation of tungsten from the individual earths and from the mixed earths is discussed. If the mixed earth acids are separated from tungsten by sodium-chloride precipitation, titration of the alkali in the precipitate furnishes a preliminary approximate determination of tantalum and niobium.

701. SCHÖNBERG, N. X-Ray Investigation of Transition Metal Phosphides. Acta Chem. Scandinavica, vol. 8, No. 2, 1954, pp. 226-239.

The X-ray investigation reported in this paper treats phosphides of transition metals with a low phosphorous content. The metals belong to the groups IV-VI of the periodic system, titanium, zirconium, vanadium, niobium, tantalum, chromium, molybdenum, tungsten. The ratio phosphorus:metal is $\leq 1$ ("subphosphides" and "monophosphides").

SCHOFIELD, H. Z. See abs. 503, 504, 505, 506, 507, 508, 745, 746.

SCHOFIELD, H. Z., LYNCH, J. F., AND DUCKWORTH, W. H. Fundamental Studies of Ceramic Materials Final Summary Report, January 1946 to March 1949. Battelle Mem. Inst., NP-1267, Mar. 31, 1949, 124 pp. See abs. 509.

SCHOVILLE, A. V. See abs. 771.

702. **SCHUBERT, J.** Effect of Zirconium and Sodium Citrate on the Distribution and Excretion of Yttrium and Plutonium. Argonne Nat. Lab., AECU-38, ANL-4206, Aug. 1, 1948, 11 pp.

This report is a confirmation of earlier work on the ability of zirconium citrate to cause increased urinary excretion of plutonium and yttrium.

703. ___. Treatment of Plutonium Poisoning by Metal Displacement. Argonne Nat. Lab., MDDC-595, December 1946, decl. Jan. 23, 1947, 4 pp.

The effect of zirconium treatment on the urinary excretion of plutonium is shown in tabular form. The administration of zirconium in rats treated shortly after the injection of plutonium was followed by as much as a 15-fold increase in the amount of plutonium excreted in the urine over a 24-hour period. When the output of plutonium had dropped, a reinjection of zirconium was followed by a second rise in the elimination rate. Tissue analyses revealed that the zirconium-treated rats had only about half as much plutonium in the skeleton and in the liver as the control animals, but the concentration of plutonium in the muscle and kidneys of the zirconium-treated animals was greater than that found in the control. The bone and liver concentrations of plutonium in the sodium citrate-treated rats did not seem to differ appreciably from those in the control animals. From a study of the toxicity of zirconium and other metals, it was concluded that zirconium was by far the safest metal to be used therapeutically. It was found that for zirconium given in single massive doses of 1.5, 1.75, and 2.0 gm./kg. body weight, 100, 50, and 0 percent, respectively, survived. No harmful chronic effects have as yet been found. Within 24 hours after the injection of zirconium, 80 to 90 percent of

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the metal was excreted in the urine. The fecal excretion of zirconium was very low (TID-3010).

See also abs. 818.

704. SCHUBERT, J., AND RICHTER, J. W. Use of Ion Exchanges for the Determination of Physical-Chemical Properties of Substances, Particularly Radiotracers, in Solution. III. The Radiocolloids of Zirconium and Columbium. Clinton Lab., AECD-2813, March 28, 1950, 8 pp.; Jour. Colloid. Sci., vol. 5, 1950, pp. 378-385.

The marked differences between cation-exchange adsorption and radiocolloidal adsorption by a synthetic cation exchanger have been shown experimentally. The tracer elements studied were $Zr^{95}$ and $NB^{95}$ in salt solutions of alkaline-earth nitrates. The composition of the alkaline-earth nitrate solutions was varied by the addition $HNO_3$, $H_2SO_4$, $H_2PO_4$, and fluosilicic and oxalic acids. From the data the relative strengths of some of the complex ions of zirconium and niobium were deduced. The applications of radiocolloidal adsorption phenomena for the separation and purification of elements by an ion exchanger were discussed (TID-3010).

705. SCHUBERT, J., AND WALLACE, H., JR. Effect of Zirconium and Sodium Citrate on the Distribution and Excretion of Simultaneously Injected Thorium and Radiostrontium. Argonne Nat. Lab., AECD-2621, Apr. 19, 1949, 20 pp.; Jour. Biol. Chem., vol. 183, March 1950, pp. 157-166.

The distribution and daily excretion of tracer levels of injected thorium and strontium were studied in rats receiving zirconium or sodium citrate intraperitoneally 1/2 hour after administration of the radioelements ("early" treated) or 3 days later ("late" treated). One group of rats received no other treatment. In contrast to previous studies on plutonium and yttrium, zirconium citrate had no specific effect on thorium or strontium metabolism other than that associated with the citrate part of the molecule. The early administration of zirconium or sodium citrate resulted in about a 3-fold increase in the urinary excretion of thorium and a 2-fold increase in the urinary excretion of strontium during the following 24 hours. No effect on the fecal excretion was found. The thorium concentration in the liver, messenteric lymph node, pancreas, and spleen was markedly reduced as a result of early sodium citrate administration. No significant changes in the metabolism of thorium or strontium were found in the late-treated groups. The deposition of thorium per gram was highest in the soft tissues, particularly in the liver, while strontium accumulated mainly in the skeleton. An interpretation of the results in terms of ion exchange, surface adsorption, and complex ion formation was presented.

706. SCHUBERT, J., AND WHITE, M. R. Effect of Citrate Salts and Other Factors on the Distribution and Excretion of Beryllium. Argonne Nat. Lab., AECU-640, UAC-169, July 1949, 20 pp.

The administration of sodium or zirconium citrate to rats 2 hours after the injection of $Be^7 - Cl_2$ increased the urinary excretion of $Be^7$. Concentration in the liver, spleen, and kidney was reduced significantly. Citrate given 6 days later did not affect $Be^7\ Cl_2$ metabolism. Calcium gluconate and the citrates of sodium, aluminum, zirconium, and thorium given to the $Be^7$ - citrate-injected rats had no effect on the distribution of excretion of beryllium (TID-3010).

707. ____. Effect of Different Dose Levels of Zirconium on the Excretion and Distribution of Plutonium and Yttrium. Jour. Biol. Chem., vol. 184, 1950, pp. 191-196.

Early administration of zirconium citrate to rats previously injected with tracer levels of plutonium, $Pu^{239}$, and yttrium, $Y^{91}$, results in a marked increase in the urinary excretion and a considerable decrease in the bone content of the injected radioelements. Relatively large amounts of zirconium, about 200 mg. per kilo, were used in these experiments. To clarify the mechanisms involved, graded dose levels ranging from 12.3 to 1,336 mg. per kilo as zirconium have been given.

708. SCHUBERT, J., AND WHITE, M. R. Effect of Sodium and Zirconium Citrates on Distribution and Excretion of Injected Radiolead. Jour. Lab. and Clin. Med., vol. 39, February 1952, pp. 260-266.

Twenty-five minutes after intravenous injection of carrier-free $Pb^{210}$ into rats, approximately 10 percent of the injected dose of $Pb^{210}$ was in the blood (essentially the cellular fraction), from which it disappeared with a half time of 30 hours. After the same interval following injection with carrier lead, only 6 percent of the injected $Pb^{210}$ was in the blood cells and approximately 22 percent in the plasma. The lead in the plasma fraction left rapidly, less than 2 percent of the dose remaining after 3 hours. Sodium or zirconium citrate injected after carrier-free $Pb^{210}$ did not affect the rate of disappearance of $Pb^{210}$ from the blood, the tissue distribution, or the fraction excreted. In rats injected with carrier amounts of lead labeled with $Pb^{210}$ zirconium citrate did not affect the immediate rate of disappearance of $Pb^{210}$ from the blood, but it caused over a three-fold increase in the $Pb^{210}$ excreted during the first 24 hours and a decrease in the kidney concentration. The sodium citrate was without effect on blood disappearance rate, tissue distribution, or excretion of the $Pb^{210}$.

709. SCHULEIN, J. Separation of Deuterium From Hydrogen. Oregon State Coll., NP-3351, 1953, 7 pp.

An outline of proposed work on the separation of $H_2$ from $D_2$ by passage over zirconium metal (TID-3010).

710. **SCHULTZ, J., TRIPP, H. P., KING, B. W., AND DUCKWORTH, W. H. Enameling of Zirconium. Battelle Mem. Inst., BMI-994, Apr. 27, 1955, 22 pp.**

**The problems involved in enameling zirconium with vitreous enamels were investigated and enamel compositions were developed. The major problems in enameling zirconium with adherent, defect-free coatings resulted from (1) The relatively low coefficient of thermal expansion of zirconium, (2) the directional thermal-expansion properties of rolled zirconium, (3) the undesirability of using enamel components of high thermal-neutron-absorption cross section, and (4) the desirability of fusing the enamel below 1,475° F. to avoid the alpha-beta transformation of zirconium when firing the coating. These problems were solved by suitable heat treatment of the zirconium to reduce directional properties and the use of a lead-silicate type of enamel. In satisfactory enamels the $SiO_2$ content ranged from about 31 to 41 w/o. PbO ranged from 53 to 64 w/o $TiO_2$, $Bi_2O_3$, or CuO was used in amounts up to 10 w/o. The content of alkaline earth oxides, ZnO, $Al_2O_3$, or $ZrO_2$ was limited to about 5 w/o. Alkali content was limited to very low percentages. Coatings were also developed for application at temperatures above the zirconium alpha-beta transformation point. In this instance the range of satisfactory compositions was much greater. $SiO_2$ content ranged from 28 to 40 w/o. PbO ranged from 22 to 64 w/o. Other components included $Al_2O_3$, $TiO_2$, $Bi_2O_3$, MgO, ZnO, or MnO in amounts up to about 10 w/o; and $ZrO_2$, CaO, or BaO in amounts up to about 5 w/o. In some instances these enamels could only be used as cover coats because they did not wet zirconium very well. Conventional methods of enamel processing and application were used.**

**SCHUMB, W. C. See abs. 77.**

711. **SCHWARTZ, B. Thermal Stress Failure of Pure Refractory Oxides. Jour. Am. Ceram. Soc., vol. 35, No. 12, December 1952, pp. 325-333.**

An investigation was carried out to study the thermal stress failure of three pure, dense refractory oxides, namely alumina, stabilized zirconia, and magnesia. Thermal stress resistances were determined by means of a direct test and by calculation from the physical properties of the material. The properties measured included strength, elasticity, and thermal expansion. All tests were conducted within the temperature range 25° to 1,500° C. For hollow cylindrical specimens, heated uniformly from the inner surface, resistance to fracture was expressed quantitatively by the heat flow at steady state required to cause fracture. This resistance was found to be a function of (1) the physical properties of the material, (2) the temperature range of testing, and (3) the temperature distribution within the specimen.

712. SCHWARTZ, C. M., AND MALLETT, M. W. Observations on the Behavior of Hydrogen in Zirconium. Battelle Mem. Inst., AECD-3510, Mar. 23, 1953, 25 pp.; Am. Soc. Metals Preprint 14, 1953, 12 pp.

Some embrittling effects noted in zirconium have been explained by the presence of hydrogen. This phenomenon was initially correlated with the existence of a second phase in the microstructure. The amount of this phase is reduced by vacuum annealing and shows a direct correlation with the hydrogen content of the specimen. X-ray and electron diffraction evidence identifies the phase as ZrH. Observations are given on the solubilities, diffusion rates, and equilibrium pressures of hydrogen in zirconium and the application of these data to the removal of hydrogen.

713. SCHWARTZ, M. A., WHITE, G. D., AND CURTIS, C. E. Crucible Handbook. Oak Ridge Nat. Lab., ORNL-1354, Apr. 17, 1953, 28 pp.

Discusses properties of commercially available nonmetallic crucibles and forming methods and stock sizes for zircon and zirconia crucibles.

714. SCHWARZKOPF, P., AND GLASER, F. W. Borides Designed for High Temperature Use. Iron Age, vol. 173, No. 13, Apr. 1, 1954, pp. 138-139.

Sintered borides of zirconium, chromium, and molybdenum, developed to meet special defense needs, have potential applications in industry. The borides are cermets with high melting points, oxidation resistance, and high-temperature strength. Thermal shock resistance is good, but impact strength is below that of cast superalloys. Molybdenum boride made from domestic base materials has cutting qualities similar to the carbides.

715. SCIENCE DIGEST. False Diamond Tells Age of Rocks. Vol. 35, January 1954, p. 14.

A brief note on zircon gem stones and the method by which this mineral tells the age of the rock formation in which it is found.

SCOTT, M. R. See abs. 807.

716. SCOTT, R. O. Effect of Electrode Dimensions on Spectral Line Intensity in the Carbon Arc. Spectrochim. Acta, vol. 4, 1950, pp. 73-84.

Results for the spectrographic determination of trace elements in an alumina matrix, obtained by carbon-arc excitation, are given for the variations in both trace element and internal standard-line intensities and in the intensity ratios caused by relatively small variations of the cathode dimensions from the normal size of 2.8 mm. outside diameter and a boring 8 mm. deep and of 0.8 mm. diameter. The elements considered are cobalt, zirconium, zinc, titanium, vanadium, molybdenum, tin, and lead, with iron as the internal standard and also zinc with cadmium, and lead with bismuth as internal standards. The dimensions altered, first with constant sample weights in the electrode, include outside diameter, depth of placement of the sample in the boring, and variation of the sample to carbon ratio in the boring; and second, with variable weights of sample in the boring, depth, and boring diameter. It is shown that variation of the electrode dimensions can alter not only the line intensities but also the intensity ratios. The excitation of the elements would appear to be most seriously affected by any variable, such as the depth of the boring, which changes the relative rates of evaporation of the elements. Other factors, such as change in the electrical characteristics of the arc by increased sample weight, appear in general to have much less effect. Accurate determinations of trace elements will be obtained only if the electrode dimensions, especially that of the electrode boring depth, are kept constant.

SCOTT, W. E. See abs. 667.

SCRIBNER, B. F. See abs. 545, 546.

SEABORG, G. T. See abs. 774.

717. SEARCY, A. W. Gaseous Species of the Boron-Boric Oxide System. Radiation Lab., Univ. California, UCRL-1404, July 20, 1951, 10 pp.

The reaction between boron and beryllium oxide has been investigated at 1,900° K. by the Knudsen effusion method. From the results, the heat of formation of BO gas is calculated to be 4.5 ± 3 kcal. Mol.$^{-1}$, and it can be shown that boric oxide vaporizes without decomposition to lower oxides. Calculations based on experiments in the literature lead to a heat of sublimation of boron of 131 ± 4 kcal. mol.$^{-1}$ and to 8.0 ± 0.2 e.v. for the dissociation energy of BO gas. The vapor pressure of $ZrO_2$ is 2.5 x $10^{-7}$ atmosphere at 2,073° K.

SEIBERT, H. C. See abs. 2.

718. SENDEROFF, S., AND BRENNER, A. Plating Experiments With Aqueous Solutions at High Temperatures. Jour. Electrochem. Soc., vol. 97, No. 11, November 1950, pp. 361-366.

Aqueous solutions of salts of chromium, copper, molybdenum, nickel, titanium, tungsten, vanadium, and zirconium were electrolyzed under pressure at temperatures up to 300° C. Under these conditions, intermediate reduction steps were favored over reduction to metal. Instability of the solutions was frequently encountered, but anodic processes were improved in some instances.

SHALIMOFF, G. V. See abs. 375.

719. SHANDS, E. H. Application of Cover Coat Enamel Directly to Steel. Finish, vol. 5, No. 12, December 1948, pp. 25-26, 46.

Outlines experiments and production tests and offers practical suggestions for the application of enamels directly to steel.

SHAPIRO, E. See abs. 516.

SHARMA, H. D. See abs. 56.

720. SHARMA, R. D., AND DHAR, N. R. Preparation and Properties of Highly Concentrated Sols. Part III. Sols of Zirconium Hydroxide. Jour. Indian Chem. Soc., vol. 9, 1932, pp. 455-461.

Results of investigation of the preparation and properties of zirconium hydroxide sol.

SHAW. L. I. See abs. 539.

721. SHAW, R. W., AND KETCHAM, H. C. Vibrational Analysis of the Hafnium Oxide Band Spectrum. Phys. Rev., Cornell Univ., vol. 45, 1934, p. 753.

Approximately 100 bands arising from the diatomic molecule HfO have been observed in an arc-flame source. The bands, which are in the region lambda 6,350 to lambda 3,330, are degraded toward the red and in many cases show double heads. In no instance is any rotational structure observed with the Hilger E-1 Littrow spectrograph, which was used in photographing the spectra. A vibrational analysis of the band heads groups the majority of the bands into two systems - gamma and beta. A poorly developed alpha system is indicated. The analysis also indicates that triplet electronic levels, which have quite large separations, are involved. The strongest bands in each system are confined to the zero sequence. In many respects this spectrum is, as might be expected, quite similar to those of TiO and ZrO. Certain of the constants of the systems are, however, larger than might be anticipated.

722. **SHEARER, W. L.** Zircon as a Constituent of Ceramic Bodies. Ceramist, vol. 5, 1926, pp. 316-328.

Occurrence, composition, characteristics, and properties of zircon. Experimental investigations on the production of bodies resistant to sudden temperature changes are discussed, and test procedures are outlined.

723. **SHELTON, S. M.** Zirconium Alloys for High Temperature Service. Wright-Patterson Air Force Base, AF-TR 5932, June 1949, 73 pp.

The primary object of this program was the development of zirconium alloys suitable for high-temperature applications. Approximately 25 alloy systems covering only the zirconium-rich portions were investigated. Heat-resistance studies conducted by means of air exposure showed that of the alloy systems investigated in the course of this work none could be considered for service above 1,400° F., and many practically disintegrated at 1,200° F. A weight gain of 600 milligrams per square decimeter per day was used as the criterion of serviceability. As the alloy additions are increased, the alloys become richer in an intermediate phase, which corresponds to $ZrX_2$ in most of the systems investigated. As for most intermediate-phase formations, the alloys become less workable as the amount of this phase increases. All alloys investigated had higher room-temperature yield strengths as the result of alloy additions. The highest yield strength of any alloy studied is about equal to Monel at the same temperature.

724. **SHEPPARD, M.** Zirconia Cements. Jour. Am. Ceram. Soc., vol. 4, 1921, pp. 662-668.

The effect of calcined zirconia on zirconia cement. Seven refractory cements were made having compositions of zirconia 90 percent and plastic clay 10 percent. (1) The shrinkage was found to be excessive in a cement containing raw zirconia and clay. The addition of 50 percent or more of calcined zirconia practically eliminated this shrinkage and the cracking that accompanies it. (2) Strength: Draw trials showed that the cement became strong at 1,200° C. and was very strong when burned at 1,700° C. (3) Load tests on piers at 1,500° C. showed that joints of these cements did not fail in any manner at this temperature. (4) An industrial test of zirconia cement used as a wash for bungs in a malleable iron furnace showed that the life of a bung was increased about 25 percent by the use of a zirconia wash.

725. **SHIRANE, G., AND HOSHINO, S.** X-Ray Study of Phase Transitions in $PbZrO_3$ Containing Barium or Strontium. Acta Cryst., vol. 7, No. 2, February 1954, pp. 203-210.

The crystal structures of various phases in (Pb-Ba) $ZrO_3$ and (Pb-Zr)$ZrO_3$ systems, the dielectric properties of which were reported previously, have been studied by the powder diffraction method. A crystal structure of a ferroelectric intermediate phase in the (Pb-Ba) $ZrO_3$ system, which can be observed between the antiferroelectric (tetragonal) and paraelectric (cubic) phases found in pure $PbZrO_3$ when the barium concentration exceeds 5 percent, is shown to be a rhombohedral modification of the perovskite structure with alpha slightly less than 90°. It is shown that, although the (Pb-Ba) $ZrO_3$ compositions from pure $PbZrO_3$ to (Pb95-Ba5) $ZrO_3$ do not show this intermediate phase, the application of a strong d.c. field can produce the rhombohedral phase just below their Curie temperatures. A crystal structure of an intermediate antiferroelectric phase in the (Pb-Sr) $ZrO_3$ system, which begins to appear when the concentration of strontium is as small as 1 percent, is found to have a tetragonal lattice with c/alpha slightly less than unity. The observed superlattice lines in this phase are different from those of the antiferroelectric phase in pure $PbZrO_3$.

726. SHIRANE, G., AND PEPINSKY, R. Phase Transitions in Antiferroelectric $PbHfO_3$. Phys. Rev., vol. 91, No. 4, Aug. 15, 1953, pp. 812-815.

Phase transitions in ceramic $PbHfO_3$ have been studied by dielectric and structural measurements. The dielectric constant is about 90 at room temperature, and its temperature dependence shows a small anomaly at 163° C. and a pronounced peak of 540 at 215° C. The P-E relation, however, is almost linear, showing no ferroelectric hysteresis loops within this temperature range. At room temperature $PbHfO_3$ has a tetragonal lattice of the perovskite type with $\alpha$ = 4.136A and $c/\alpha = 0.991$ and a powder X-ray photograph shows some superstructure lines, which have essentially the same character as those of $PbZrO_3$. This shows that $PbHfO_3$ is an antiferroelectric of the $PbZrO_3$ type below 163° C. The crystal structure between 163° C. and 215° C. is also based on a tetragonal lattice; but the axial ratio $c/\alpha$ is much closer to unity (0.907), and the observed superstructure lines are different from those of the lowest phase. Thus, the intermediate phase is another antiferroelectric phase, with a different type of dipole arrangement from that of the lowest phase. At 215° C. it becomes paraelectric, accompanied by change to a cubic structure.

727. SHIRANE, G., SAWAGUCHI, E., AND TAKAGI, Y. Dielectric Properties of Lead Zirconate. Phys. Rev., vol. 84, No. 3, Nov. 1, 1951, pp. 476-481.

To distinguish whether or not it is really a ferroelectric, the dielectric response of $PbZrO_3$ ceramic to biasing d.c. field has been examined. In contrast to ordinary ferroelectrics an effect is scarcely detected below the Curie point of 233° C., even up to a field strength of 20 kv./cm., except for a slight increase of permittivity at the vicinity of the transition point. In addition, the Curie temperature decreases with increasing biasing field attaining the value $\Delta T_c = 1.7°$ C. for 20 kv./cm. The hysteresis loops of this ceramic have been studied. So long as the amplitude of the applied a.c. field is less than a critical field of about 23 kv./cm., the D-E curves are almost always linear, except that a slight upward curvature becomes perceptible just at the temperature range wherein permittivity increases and never shows any hysteresis characteristics even just below the Curie point. But if the amplitude of the applied field is greater than this threshold value, anomalous hysteresis loops of very impressive form are observed in a narrow temperature range just below the Curie point. These experimental facts all seem to suggest that $PbZrO_3$ may not be a ferroelectric but an antiferroelectric. A preliminary pyroelectric test also seems to show that no net polarization grows spontaneously when the sample is cooled through its Curie point.

728. SHIRANE, G., SAWAGUCHI, E., AND TAKEDA, A. Phase Transition in Lead Zirconate. Phys. Rev., vol. 80, 1950, p. 485.

Ceramic $PbZrO_3$ was prepared by sintering mixtures of $ZrO_2$ and PbO at temperatures near 1,100°. The permittivity is reported from -160° to 320°; there is a transition near 222°, with a maximum value more than 15 times the value at room temperature. The specific heat is reported from 60° to 340°; there is a large anomaly at the Curie point. The transition energy is about 400 cal./mole; the entropy change is about 0.4 R. The thermal expansion is reported from -160° to 320°, and there is an anomalous volume expansion at 223°. The volume change is 0.18 $A^3$/unit cell. The coefficient of linear expansion is ~ 0.0000095 both below and above the Curie point. Results are compared with those for $BaTiO_3$ (TID-3010).

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729. **SHIRANE, G., AND TAKEDA, A.** Phase Transitions in Solid Solutions of $PbZrO_3$ and $PbTiO_3$ I. Small Concentrations of $PBTiO_3$. Jour. Phys. Soc. of Japan, vol. 7, No. 1, January-February 1952, pp. 5-11.

The dielectric, calorimetric, and dilatometric measurements have been made on the solid solutions $Pb(Zr\text{-}Ti)O_3$, which contain small amounts of $PbTiO_3$ less than 10 percent. Besides the ordinary Curie point near 220° C., the existence of another transition, for example 140° C. in $Pb\ (Zr95\text{-}Ti5)O_3$, was confirmed. It seems reasonable to interpret these two transitions as phase changes from paraelectric state to ferroelectric one and further to antiferroelectric one, whereas the upper transition temperature is nearly constant for these concentrations, the lower transition temperature increases with decreasing titanium concentration, and both temperatures seem to coincide at pure $PbZrO_3$. These results suggest that $PbZrO_3$ may be antiferroelectric below its Curie point 220° C.

730. **SHIRANE, G., SUZUKI, K., AND TAKEDA, A.** Phase Transitions in Solid Solutions of $PbZrO_3$ and $PbTiO_3$. II. X-Ray Study. Jour. Phys. Soc. of Japan, vol. 7, No. 1, January-February 1952, pp. 12-18.

The phase diagram of the whole range of the PbZrO-PbTiO system was determined by the dielectric and dilatometric measurements. This phase diagram can be divided into three regions - paraelectric, ferroelectric, and antiferroelectric phases. The crystal structure of this system was determined by the Debye photographs. In the antiferroelectric region solid solutions have a tetragonal modification of perovskite structure with $c/\alpha < 1$ and have some superstructure which seems to have intimate relation to the antiferroelectricity. In the ferroelectric region, except a region near antiferroelectric phase in which pseudocubic structure is observed, they have ordinary tetragonal structure of $c/\alpha < 1$ without any superstructure.

731. **SHOENS, C. J., AND SHORTALL, J. W.** Thermoelectric Calibration of Zirconium-Constantan and Zirconium-Alumel Thermocouples. Livermore Research Lab., California Research and Development Co., LRL-62, December 1953, 17 pp.

Data are presented in tables on the calibration of zirconium-constantan and zirconium-alumel thermocouples from 0°-600° C. Statistical analyses of the data show that the e.m.f. versus temperature values obtained in this experiment should be accurate to ± 2° C. in the first case and ± 5° C. on the average in the latter case.

732. **SHORE, F. J., BENDEL, W. L., BROWN, H. N., AND BECKER, R. A.** Radiations from $Zirconium^{89}$. Phys. Rev., vol. 91, No. 5, Sept. 1, 1953, pp. 1203-1211.

A betatron-induced gamma, n reaction on $Zr^{90}$, has been found to produce a third branch in the decay of the 4.4-minute state of $Zr^{89}$. The new branch includes a 1.53-Mev. gamma ray (8 percent as intense as the 588-kev. gamma ray) coincident with positrons of approximately 850-kev. maximum energy. These particles (log ft. = 4.2 ± 0.1) are in competition with the 2.4-Mev. positron group (log ft. = 6.9 ± 0.3) emitted in the decay, to the ground state of $Y^{89}$, of the 4.4-minute $Zr^{89m}$. Anomalous behavior of the comparative half lives is indicated, since both the 2.4-Mev. and the 901-kev., 79-hour positron transitions are thought to be allowed. K/(L+M) conversion ratios for the 4.4-minute, 588-kev., and the 79-hour, 913-kev. gamma radiations are, respectively, 5.4 ± 0.7 and 7 ± 2. A 10 channel scintillation spectrometer, based on a cathode-ray tube, light pipes, and photomultiplier tubes, to effect pulse-height selection, is also described.

**SHORTALL, J. W.** *See* abs. 731.

**SHUBERT, J.** *See* abs. 534.

**SHULL, C. G.** See abs. 676.

733. SHURE, K., AND DEUTSCH, M. Radiations From Zirconium$^{89}$. Phys. Rev., vol. 82, Feb. 13, 1951, p. 122.

Research has been carried out in the M.I.T. cyclotron on $Zr^{89}$. Results indicate the level emitting the conversion electrons has a lifetime considerably greater than the resolving time of the coincidence circuit used ($10^{-7}$ seconds).

SIBERSTEIN, F. See abs. 539.

SIBERT, M. E. See abs. 766.

734. SIDHU, S. S. Effect on Metal-Metal Bonds of Increasing Concentration of Hydrogen in Hafnium Dihydride. Acta Cryst., vol. 7, No. 5, May 20, 1954, pp. 447-449.

A tetragonal unit cell of hafnium dihydride is formed at a composition of $HfH_{1.87}$. Each metal atom has 12 hafnium atoms as its neighbors, 8 at a distance 3.289 ± 0.002 Å and 4 at 3.461 ± 0.002 Å; they constitute short and long metal-metal bonds, respectively. As the concentration of hydrogen atoms is increased, the dihydride structure exhibits anisotropic changes; $a_0$ increases and $c_0$ decreases. It is shown that the anisotropy arises from the additional metal-gas bonding, which strengthens the short and weakens the long metal-metal bonds.

735. SIDHU, S. S., AND McGUIRE, J. C. X-Ray Diffraction Study of the Hafnium-Hydrogen. Argonne Nat. Lab., AECU-2042, Apr. 29, 1952, 16 pp.; Jour. Appl. Phys., vol. 23, No. 11, November 1952, pp. 1257-1261.

The hafnium-hydrogen system at room temperature consists of three phases. The lattice parameters of the hafnium metal used in this investigation and of the three phases are as follows: Hafnium, $a_0 = 3.200$ A, $c_0 = 5.061$ A, and c = 1.58; deformed cubic phase, $a_0 = 4.702 \pm 0.012$ A, $c_0 = 4.678 \pm 0.012$ A, and c = 0.995; face-centered cubic phase, $a_0 = 4.708 \pm 0.002$ A; and face-centered tetragonal phase, $a_0 = 4.882 \pm 0.002$ A, $c_0 = 4.384 \pm 0.002$ A, and c = 0.898. The deformed cubic phase extends up to $HfH_{1.53}$ and converts into the face-centered cubic phase between $HfH_{1.53}$ and $HfH_{1.70}$. The face-centered cubic phase transforms into the tetragonal phase between $HfH_{1.80}$ and $HfH_{1.87}$. The tetragonal phase extends up to $HfH_{1.98}$.

SILKES, B. See abs. 180.

736. SILVERMAN, M. Wonder Metal That Blows Its Top. Saturday Evening Post, vol. 225, Nov. 8, 1952, pp. 34, 124, 126, 128.

Development, characteristics, and uses of zirconium metal.

737. SIMCOCK, J. H. Notes on Ceramic Cordierite. Ceramics, vol. 1, 1949, pp. 343-350.

Ceramic cordierite bodies are synthetic cordierite ($MgO.Al_2O_3.SiO_2$), based on mixtures of $Al_2O_3$, talc, and clay. They have an extremely low and regular coefficient of thermal expansion. They melt below 1,400° and usually have a maximum operating temperature of 1,200°. They have a narrow firing range (sometimes <20°). It is almost impossible to distinguish underfired ware from that properly fired, except by measurement of the thermal expansion. The narrow firing range can be overcome by firing in tunnel ovens of small cross section, by the use of stabilizing agents, $ZrO_2$, in the body mix, by paying particular attention to firing and cooling, and by the addition of a little ground cordierite grog (TID-3010).

SIMON, F. See abs. 467.

738. SIMPSON, A. G., AND BERRY, B. E. Production, Fabrication and Applications of Molybdenum, Tungsten, Tantalum, and Zirconium Sheet. Sheet Metal Ind., vol. 30, No. 313, May 1953, pp. 397-405.

Interest in the fabrication of parts comprising these rare metals has been increasing rapidly during the last few years. As experience in the forming and shaping of these metals increases, new uses will be found for them, and metals that once were almost unknown, except in certain specialized industries, will be no longer "rarer metals" but will be in general use throughout industry wherever their special properties present advantages over the more common metals. The corrosion-resisting properties of zirconium make it particularly adaptable to the new uses.

739. **SIMS, C. E., SALLER, H. A., AND BOULGER, F. W.** Effects of Various Deoxidizers on the Structures of Sulfide Inclusions. Trans. Am. Foundryman's Soc., vol. 57, 1949, pp. 233-248.

Describes procedures followed and data obtained in a study of the effects of additions of 10 elements on the inclusion characteristics. All these elements have, or have been reputed to have, deoxidizing effects in steel.

**SCHOELLER, W. R.** See abs. 631.

**SINDEBAND, S. J.** See abs. 599.

**SINGH, S.** See abs. 45.

**SKEHAN, J. W.** See abs. 154.

740. **SKINNER, G. B., BECKETT, C. W., AND JOHNSTON, H. L.** Thermal, Structural, Electrical, Magnetic and Other Physical Properties of Titanium, Zirconium, Hafnium and Thorium and Some of Their Simple Compounds. II. Zirconium, Its Hydrides, Oxides, Halides, Nitride, Carbide and the Alkaline Earth Zirconates. Ohio State Univ., PB-106166, ATI-81815, Feb. 1, 1950, 69 pp.

Reviews literature on preparation and properties of zirconium, its hydrides, oxides, halides, nitride, and carbide; and the alkaline earth zirconates; methods of preparation, crystal structure, density, transitions between forms, thermal function, heat of formation, thermal expansion, electrical resistance, and other properties. Although in many instances the information is incomplete or unreliable, an attempt has been made to correlate and evaluate the data of the different experimenters.

741. ___. Thermal, Structural, Electrical, Magnetic and Other Physical Properties of Titanium, Zirconium, Hafnium and Thorium and Some of Their Simple Compounds. III. Hafnium, Its Oxides, Halides, Carbide and the Alkaline Earth Hafnates. Ohio State Univ., ATI-81814, Tech. Rept. 102-AC49/2-100-3, Feb. 1, 1950, 19 pp.

Reviews literature on preparation and properties of hafnium, its oxides, halides, and carbide; and of strontium hafnate; methods of preparation, crystal structure, density, transitions between forms, thermal functions, heat of formation, thermal expansion, electrical resistance, and other properties. Although in many instances the information is incomplete or unreliable, an attempt has been made to correlate and evaluate the data of the different experimenters.

742. **SKINNER, G. B., EDWARDS, J. W., AND JOHNSTON, H. L.** Vapor Pressure of Inorganic Substances. V. Zirconium Between 1,949° and 2,054° K. Ohio State Univ., NP-1818, ATI-94876, July 27, 1950, 12 pp.; Jour. Am. Chem. Soc., vol. 73, January-March 1951, pp. 174-176.

The vapor pressure of zirconium has been determined in the temperature range 1,949° to 2,054° K. by measuring the rate at which a zirconium surface evaporates into a vacuum. Values of $\Delta H^\circ_0$ have been calculated from the individual vapor pressures and show no appreciable trend, the average value being 142,150 ± 350 cal./mol. By combining this value with free-energy functions of gaseous zirconium and with extrapolated values for the solid, the following equation for vapor pressure is obtained:

$$\log P\ (\text{atm}) = -\frac{31{,}066}{T} + 7.3351 - 2.415 \times 10^{-4} T$$

743. SKINNER, G. B., AND JOHNSTON, H. L. Thermal Expansion of Zirconium Between 298° K. and 1,600° K. Jour. Chem. Phys., vol. 21, No. 8, August 1953, pp. 1383-1384.

The fact that zirconium crystallizes in the close-packed hexagonal lattice at room temperature and in the body-centered cubic lattice in the temperature range above the transition (at about 1,143° K.) has been known for some time. Owing to the anisotropic crystal structure at lower temperatures, there is some question as to the meaning of measurements reported by Zwikker (Physica, vol. 6, 1926, p. 361), Squire and Kaufman (Jour. Chem. Phys., vol. 9, 1941, p. 673) and Adenstadt (Trans. Am. Soc. Metals, vol. 44, 1952, p. 949), of the thermal expansion of bulk samples of zirconium. In an attempt to clarify these measurements the two expansion coefficients of hexagonal zirconium have been determined by using the X-ray diffraction method, and the isotropic expansion of cubic zirconium has been measured by the conventional comparator method.

744. SKONIECZNY, R. F. Structural Chemistry of Zirconium Compounds. Record of Chem. Prog., vol. 14, No. 3, 1953, pp. 143-149.

Discusses the work of other authors dealing with valence, ion species, molecular structure, coordination numbers, and the complex compounds of zirconium.

SLEIGHT, N. R. See abs. 799.

745. SLYH, J. A., SCHOFIELD, H. Z., AND AUSTIN, C. R. Carbon or Graphite as Materials of Construction for Rocket Motors. (Rept. 40, Nov. 15 to Dec. 15, 1947.) Battelle Mem. Inst., NP-381, 9 pp.

Data covering an investigation of the use of a molybdenum-alloy coating or a silicon carbide coating as means to prevent oxidation of graphite at elevated temperatures. Data also are reported on an investigation of mixtures of aluminum, graphite, and pitch, with varying quantities of silicon carbide and magnesia or zirconia.

746. ___. Refractory Oxides as Materials of Construction for Rocket Motors. (Rept. 37, Oct. 15 to Nov. 15, 1947.) Battelle Mem. Inst., NP-197, 16 pp.

Data showing the influence of the following factors on the resistance of the sintered shellac-bonded magnesia body to the torch-firing test: (1) Burning temperature, (2) addition of small quantities of water, and (3) addition of small quantities of magnesium fluoride. Describes the results of torch-firing tests on specimens machined from blocks of dolomite or formed from a mixture of plaster of Paris, graphite, and zirconium oxide. Discusses a preliminary study of several metal-metal oxide bodies.

747. SMITH, A. Zircon Sand, Properties, and Uses in Cores and Facings. Am. Foundryman, vol. 19, No. 5, May 1951, pp. 64-67.

Discusses the use of zircon sand as a core and facing material. Indications are that the use of zircon sand results in substantial savings in cleaning casts and in the production of superior-quality steel castings.

748. SMOKE, E. J. Thermal Endurance of Some Vitrified Industrial Compositions. Ceram. Age, vol. 54, No. 3, September 1949, pp. 148-149.

The work discussed in this report is an empirical determination of the thermal endurance of some vitrified industrial compositions of high thermal endurance. Also, the transverse strength, relative thermal conductivity, and coefficient of thermal expansion were evaluated to ascertain their values in thermal endurance.

749. SNAVELY, F. A., AND FERNELIUS, W. C. Studies on the Zirconium Derivatives of Beta-Diketones. Pennsylvania State Coll., PSC-2, July 1950, 38 pp.

A number of zirconium derivatives of several beta-diketones were prepared and their volatility tested. The behavior of each beta-diketone in alkaline titration was studied. The acid dissociation constant of material can be estimated from a simple titration of the beta-diketone itself. From a titration of the ($ZrO^{+2}$) in the presence of the beta-diketone, the formation constant of chelate compound can be estimated.

750. SOMERVILLE, I. C. Chrome and Zirconium Tannages. A Review and Comparison. Jour. Soc. Leather Trades' Chemists, vol. 38, No. 10, October 1954, pp. 347-358.

History and practical applications of zirconium tannage.

751. ___. Zirconium Tannage. I. Tanning Properties of Zirconium Salts. Jour. Am. Leather Chemists' Assoc., vol. 37, 1942, pp. 381-390.

An outline of the development of zirconium salts as tanning materials. Of a number of salts tried, the basic sulfate was selected as the most effective and has been used to produce stable white leather. A technical zirconyl sulfate in dry form has been developed for tannery use.

See also abs. 752.

752. TURLEY, H. G., AND SOMERVILLE, I. C. Zirconium Tannage. II. Development of the Zirconium Tannage for White Leathers. Jour. Am. Leather Chemists' Assoc., vol. 37, 1942, pp. 391-397.

Discusses the application of zirconium tannage to various types of leathers and shows it to be economical and successful. Zirconium tannage can be combined with other tannages such as chrome, alum, formaldehyde, syntans, and vegetable tans.

753. SOMERVILLE, I. C., AND TURLEY, H. G. Zirconium Tannage. III. Chrome-Zirconium Tannages. Jour. Am. Leather Chem. Assoc., vol. 38, 1943, pp. 326-332.

The study of the tanning action of zirconium salts has been extended to cover chrome-zirconium tannages. It has been found that zirconium can be substituted for part or all of the chrome to give leather of comparable quality to that made with a full chrome tannage. Zirconium can also be used as a retan to give additional weight to chrome leather. A cheaper product, Zircotan Tech., has been developed, which should enable zirconium to be considered as a practical substitute for chrome.

754. ___. Zirconium Tannage. IV. Recent Applications of Zirconium Salts in Practical Tanning. Jour. Am. Leather Chemists' Assoc., vol. 43, 1948, pp. 345-351.

Applications for the utilization of zirconium by the tanning industry and special reference to its use on white leathers.

755. SOMERVILLE, I. C., AND RAU, W. J. Zirconium Tannage. V. Review of Complex Zirconium Sulfates and Consideration of Their Application in Tanning. Jour. Am. Leather Chemists' Assoc., vol. 44, 1949, pp. 784-795.

Reviews literature on zirconium sulfates and especially on sodium zirconium sulfates. Experiments have been run to try to prepare some of the latter, whose isolation has been previously described, and the products obtained have been used in tanning pickled skins. All behaved similarly, giving good leather under the conditions normally employed. Some new evidence has been advanced that at the concentrations used in tanning the zirconium is present in a cationic condition.

SOPHER, R. P. See abs. 594.

756. SPEDDING, F. H., AND McGINNIS, W. J. Preparation of Rare Earth Metals. Ames Lab., Iowa State Coll., ISC-149, June 1951, 29 pp.

Describes the production of over 400 grams of pure gadolinium metal by reduction of the anhydrous chloride by calcium in tantalum vessels; yields were over 97 percent. The use of the same techniques in an attempt to prepare yttrium metal were partially successful. Mentions the use of zirconium as a reductant.

757. SPETER, M. Precipitation of Zirconium With Picric Acid. Continental Met. and Chem. Eng. (Berlin), vol. 1, October 1926, p. 83.

A method for the precipitation of zirconium by picric acid in the presence of iron.

758. SPIEGL, C. J., AND CALKINS, M. C. $ZRCl_4$ Mist Inhalation at 20 mg./m.$^3$. Deposition and Retention in Tissues. (Ch. in Quart. Tech. Rept., Oct. 1 - Dec. 31, 1950, by H. A. Blair.) Rochester Univ., UR-152, Feb. 1, 1951, pp. 109-116.

The deposition and retention of zirconium was studied in a total of 65 animals (rats, guinea pigs, rabbits, cats, and dogs) exposed by inhalation to a mist of $ZrCl_4$ ($ZrOCl_2$) at a concentration of 20 mg./m.$^3$, which produced little or no toxicity in any species. Exposure lasted for 60 calendar days (270 hours). The animals were sacrificed, and samples were taken for spectrographic analysis of selected tissues. The lung and pulmonary lymph nodes were found to contain 55 to 361 μg Zr/g. These values were~100 to 1,000 times higher than were found for kidney, liver, or femur. A serial study of rats showed rapid deposition and slow elimination of zirconium by the lung. Mobilization from the lung appeared to take place via the pulmonary lymph node. There is a suggestion of a species difference either in the deposition or mechanism of mobilization of zirconium from the lung (TID-3010).

SPINK, D. R. See abs. 70.

SQUIRE, C. See abs. 258.

759. SRINIVASAN, R., AND HAZRA, G. D. Studies in the Catalytic Production of Butadiene From Ethanol. Part III. Sci. and Cult., vol. 14, No. 12, June 1949, pp. 532-533.

Reports an investigation of the utilization of zirconium oxide as one of the dehydrating components in the catalyst for the one-step conversion of ethanol to butadiene.

STACY, J. T. See abs. 685.

760. STALEY, W. W. Distribution of Heavy Alluvial Minerals in Idaho. Idaho Bureau of Mines and Geol. Miner. Res. Rept. 5, March 1948, 12 pp.

Contains a survey of various minerals, including zircon, in the State of Idaho.

761. STALEY, W. W., AND BROWNING, J. S. Preliminary Investigation of Concentrating Certain Minerals in Idaho Placer Sand. Idaho Bureau of Mines and Geol. Pamphlet 87, June 1949, 23 pp.

Covers the investigation of heavy minerals of Idaho placer sands, with particular emphasis on zircon, monazite, ilmenite, and magnetite.

762. STANTON, R. B. Sampling and Testing Titanium. Modern Machine Shop, vol. 26, No. 1, June 1953, pp. 136-138.

A practical receiving inspection and sampling procedure for titanium, also applicable to zirconium.

STAUFFER, R. A. See abs. 203, 204, 205, 206.

763. STEEL HORIZONS. New Metals for the Atomic Age. Vol. 15, No. 1, 1953, pp. 2-5, 26.

Discusses the future of zirconium and other similar metals.

764. STEINBACH, J. F. Acetylacetone as an Analytical Extraction Agent. Univ.

Original from THE OHIO STATE UNIVERSITY

Pittsburgh (Thesis), NYO-6347, 1953, 120 pp.

Shows that acetylacetone-water systems are well suited for theoretical study of the extraction behavior of metal chelates and permit a number of practical separations. Zirconium acetylacetonate is included in the experimental work. The characteristics of an acetylacetone-water system may be summarized as follows: (1) The solubility of acetylacetone in dilute sulfuric acid is constant enough between pH 0 and 7 to enable equilibrium extraction curves to be obtained without making corrections for change in reagent concentration caused by either distribution or chelation. (2) The solubility of acetylacetonates in acetylacetone is enough to permit macro as well as micro extractions to be performed. (3) The high reagent concentration in the water layer permits extraction in more acid solutions and minimizes the effect of hydrolysis. It also increases the rate of attaining equilibrium and thus assures reproducibility of extraction data. (4) The wide variation of the $p_c$ values in this system may permit additional separations not possible in other systems.

765. STEINBERG, E. P. Oxalate Method for Determination of Zirconium and Niobium Activities in Fission. (Ch. in Radiochem. Studies.) The Fission Products, Nat. Nuclear Energy Series, book 3, vol. 9, No. 6, (McGraw-Hill Book Co., Inc., New York, N. Y., edited by C. D. Coryell and N. Sugarman), 1951, pp. 1495-1497.

Outlines a rapid method for separating zirconium and niobium from fission-product mixtures. Satisfactory decontamination from other fission elements is indicated.

766. STEINBERG, M. A., SIBERT, M. E., AND WAINER, E. Extractive Metallurgy of Zirconium by the Electrolysis of Fused Salts. II. Process Development of the Electrolytic Production of Zirconium From $K_2ZrF_6$. Jour. Electrochem. Soc., vol. 101, No. 2, February 1954, pp. 63-78.

An intensive investigation of the electrolysis of $K_2ZrF_6$ in an electrolyte of NacL has been made to determine the optimum conditions for the production of zirconium metal by fused-salt electrolysis. Cell designs and conditions of operation evolved, yielding a high-purity zirconium powder that is ductile on consolidation are described. This metal can be fabricated easily and is comparable with Kroll zirconium sponge. Because of the stability of the raw materials, their ease in preparation and in electrolysis, coupled with lower cost equipment, it is probable that this process will yield a much lower cost zirconium metal.

767. STELSON, P. H., AND GOODMAN, C. Inelastic Scattering of 15-Mev. Neutrons by Lead, Iron and Aluminum. Phys. Rev., vol. 82, No. 1, Apr. 1, 1951, pp. 69-71.

A tritium-zirconium target, bombarded by 1.0-Mev. deuterons from the Rockefeller electrostatic generator, was used as a source of high-energy (~15-Mev.) neutrons. This source was surrounded by lead, iron, and aluminum scatters with dimensions of approximately one mean free path for inelastic scattering. The resulting neutron spectra were measured by means of proton recoils in photographic emulsions. An exposure without scatterer permitted an evaluation of the upper limit for the neutron background. The spectra indicate that most of the neutrons are inelastically scattered to energies below 3 Mev. in the case of the lead and iron scatterers and to below 5 Mev. with the aluminum acatterer. The data can be represented by a curve of the form (const $Ee^{-E/T}$) as predicted by the Weiskopf statistical theory. The values obtained for the nuclear temperatures, T, are 0.7, 0.6 and 1.1 Mev. for lead, iron, and aluminum, respectively. The fact that the measured temperatures for iron and lead are approximately the same supports the hypothesis that lead nuclei have a closed-shell structure and therefore have properties similar to much lighter nuclei.

STEPHAN, D. J. See abs. 3.

STEPHENS, W. W. See abs. 464, 465, 466.

768. STEPHENSON, R. J. X-Ray Fluorescence Yields. Phys. Rev., vol. 51, Apr. 15, 1937, pp. 637-642.

The X-ray fluorescence yield for the K shell of atoms has been measured for a number of elements ranging from nickel to tin by an ionization-chamber method similar to that developed by A. H. Compton. The results show an increase in the fluorescence yield with atomic number and are compared with those calculated by Massey and Burhop, using relativistic wave mechanics, and also with those calculated by Burhop from nonrelativistic wave mechanics. The fluorescence yield for the $L_{III}$ shells of lead, thorium, and uranium has been determined, using suitable exciting radiation. An increase in the yield with atomic number is found.

769. STEVENSON, W. W. Chemical Analysis of Modern Alloy Steels, Carbon, Silicon, Sulfur, Phosphorus, Manganese, Nickel, Chromium, Copper, Aluminum, Tungsten, Molybdenum, Cobalt, Vanadium, Titanium and Zirconium. Ind. Chem., vol. 8, June 1932, pp. 213-216; July 1932, pp. 256-259; August 1932, pp. 291-294; September 1932, pp. 320-323.

Outlines methods for the determination of carbon, silicon, sulfur, phosphorus, manganese, nickel, chromium, copper, aluminum, tungsten, molybdenum, cobalt, vanadium, titanium, and zirconium.

STEWART, J. See abs. 382.

770. STEWART, W. J. Rare Metal Soaps and the Paint Industry. Off. Dig. Federation Paint and Varnish Production Clubs, vol. 26, No. 353, June 1954, pp. 413-425.

Evaluates on a comparable basis the effectiveness of metals including zirconium as drying catalysts.

771. STOCK, J. E., AND SCHOVILLE, A. V. Casting Precision Patterns in Zircon Molds. Am. Foundryman, vol. 27, No. 4, April 1955, pp. 34-37.

Outlines in detail a process method for producing gray iron patterns to precision tolerances in zircon sand molds.

STOTT, V. H. See abs. 358.

772. STOTT, V. H., AND HILLIARD, A. Zircon Refractories. Trans. British Ceram. Soc., vol. 48, 1949, pp. 133-139.

When zircon bricks are fired for 1 hour to at least 1,650° C., remarkable resistance to lead and slag attack at high temperatures results, and the adverse effects of fluxing impurities can be greatly reduced by hard firing. It is nevertheless advantageous for the content of such impurities to be kept low. The effects of various additions to zircon, and of various heat treatments are discussed, and a probable explanation is given.

773. STOUT, P. R., OVERSTREET, R., JACOBSON, L., AND ULRICH, A. Use of Radioactive Tracers in Plant Nutrition Studies. Soil Sci. Soc. Am. Proc., vol. 12, 1947, pp. 91-97.

Concerns the application of radioactive isotopes to studies in soils and plant nutrition. Nineteen radioelements, including zirconium, were investigated. Methods of detection and their level of sensitivity are discussed.

774. STREET, K., JR., AND SEABORG, G. T. Ion Exchange Separation of Zirconium and Hafnium. Radiation Lab., Univ. California, AECD-2435, Oct. 11, 1943, decl. Nov. 10, 1948, 2 pp.

Elution of milligram amounts of zirconium and hafnium in dilute perchloric acid from cation exchange resin Dowex 50 with 6M hydrochloric acid effects a separation.

STRIETER, F. P. See abs. 590.

775. **STROM, P. O., BOYER, M. H., AND LITZ, L. H.** Aqueous Static Corrosion of Aluminum Alloys Coupled to Stainless Steel and Zirconium at 350° F. Livermore Res. Lab., LRL-74, January 1954, 13 pp.

The corrosion of several commercial aluminum alloys, electrically coupled to type 302 stainless steel and to zirconium, was studied at 350° F. in pure water. Those aluminum alloys coupled to steel showed appreciably higher initial rates of attack than those coupled to zirconium. Roughly equal rates were observed once the protective film of corrosion product had formed. Long-term corrosion rates were about the same as for uncoupled aluminum alloys, about 0.35 mils per year at this temperature.

776. **SUGARMAN, N.** Photo-Fission of Bismuth. Phys. Rev., vol. 79, 1950, pp. 532-533.

By use of a betatron at a maximum energy of 85 Mev., photofission of bismuth was obtained. Photofission results were reported on 17-hour zirconium$^{97}$, 3.0 percent, and other elements.

777. **SUMMERS-SMITH, D.** Constitution of Uranium-Zirconium Alloys. Jour. Inst. Metals, vol. 83, February 1955, pp. 277-282.

The uranium-zirconium system has been examined by metallographic, dilatometric, and X-ray methods, using alloys prepared by arc melting. A continuous series of body-centered-cubic solid solutions is formed between gamma-uranium and beta-zirconium. At 14.5 atomic-percent zirconium the gamma phase exists up to 693° ± 3° C., where it undergoes a monotectoid reaction; at 69.5 atomic-percent zirconium it exists up to 606° ± 3° C., where it transforms by a eutectoid reaction. A miscibility gap is formed at 693° C. from 14.5 to about 57 atomic-percent zirconium; this reaches a maximum at 740° ± 5° C. and 34 atomic-percent zirconium. The maximum solubility of zirconium in beta-uranium is 2.5 atomic-percent at 693° C.; the beta solution transforms by a eutectoid reaction at 662° ± 2° C., $c_a$ 1.5 atomic-percent zirconium. The maximum solubility of zirconium in alpha-uranium at the eutectoid is placed tentatively at about 1 atomic-percent; the eutectoid transformation extends to approximately 61 atomic-percent zirconium. The solubility of uranium in alpha-zirconium is estimated to be 0.75 atomic-percent at 606° C. It was not found possible to completely retain the gamma solution by quenching either lumps or powders containing up to 35 atomic-percent zirconium. It was retained completely, however, in the 40 atomic-percent zirconium alloy. The beta-uranium solution, containing 2.5 atomic-percent zirconium, could not be retained by quenching.

**SUMMERS-SMITH, D.** See abs. 278.

**SUMYAR, A. W.** See abs. 300.

**SUNDARAM, A. K.** See abs. 56.

**SUTTON, E. E.** See abs. 536.

**SUZUKI, K.** See abs. 730.

778. **SWANGER, W. H., AND CALDWELL, F. R.** Special Refractories for Use at High Temperature. Jour. Res., Nat. Bureau Standards, vol. 6, 1931, pp. 1131-1143.

The choice of the most suitable refractory for the laboratory melting of pure metals at temperatures from 1,700° up to 2,200° C., without detrimental contamination of the metal by the refractory, depends upon a number of factors, such as the stability of the refractory at the higher temperatures, the means available for forming and firing crucibles, the type of melting furnace, chemical action of the particular metal in question, etc. Methods are described in detail for the preparation of crucibles and other shapes from the oxides of thorium, magnesium, zirconium, and beryllium. Thorium oxide, with a melting point above 3,000° C., is the most refractory of the four oxides named. The method used for fusing this oxide is described. Crucibles of fused thorium oxide have been used in the determinations of the melting points of platinum and rhodium. Crucibles of the commercial fused magnesium oxide are not satisfactory for work with metals of the highest purity, but crucibles prepared from the so-called "C. P." or reagent grade of powdered magnesium oxide have been used at temperatures up to 2,000° C. without detrimental effect upon the metal melted. The commercial electrically fused or sintered zirconium oxide contains small amounts of silica. Crucibles of this material have been used at temperatures up to 2,000° C., but unless the melting is done in air, there is danger of contamination of the metal by the silicon in the refractory. Indications from a few experiments with a small amount of the very pure oxide are that, if available commercially, beryllium oxide might be a satisfactory refractory for use at high temperatures.

SWANWICK, J. D. See abs. 98.

SYKES, A. See abs. 71.

T

TAKAGI, Y. See abs. 727.

TAKEDA, A. See abs. 728, 729, 730.

779. **TANAKA, T., AND HORIE, T.** Rotational Analysis of Gamma System of ZrO Bands. Proc. Physico-Math. Soc. (Japan) vol. 23, 1941, pp. 464-484.

The rotational analysis of the gamma-system bands has been done; the third-order emission spectra, due to 21-foot concave grating, was used. These bands can be attributed to the transition of $^{3}\Sigma \rightarrow {}^{3}\mathrm{II}$, of which the final state coincides with that of the alpha system. The trebling of the level with each value of K in the $^{3}\Sigma$ state cannot be found, and the levels for small values of K of the branches $\upsilon' = 0$ undergo peculiar perturbations. The $^{3}\mathrm{II}$ state gives an example approximating case a. The following values of the rotational constants have been obtained:

$$B'_e = 0.5658 \mathrm{cm}^{-1}, \; \alpha'' = 0.0077, \; \nu' e = 1.477 \times 10^{-8} \mathrm{cm},$$

$$B''_e = 0.6189 \mathrm{cm}^{-1}, \; \alpha'' = 0.0038, \; \nu'' e = 1.412 \times 10^{-8} \mathrm{cm}.$$

The constants of the final state are quite near those obtained by Lowater for alpha system. The lambda-type separations in the $^{3}\mathrm{II}$ state have been determined. The isotope effect is discussed.

TATLOW, J. C. See abs. 71.

780. **TAYLOR, H. S., AND FEHRER, H.** Mechanism of Reaction and of Poisoning in the Dehydroaromatization of n-Heptane. Jour. Am. Chem. Soc., vol. 63, May 1941, pp. 1387-1392.

Data on the comparative rates of reaction of n-heptane, heptylene-1, and methylcyclohexame from the standpoint of yields and poisoning; in addition, data on the effect of poisoning by ethylene as a typical olefin. Data on the course of olefin and aromatic production during a run in which n-heptane reacted at 475° under standard conditions on a catalyst $Cr_2O_3$ - 10 percent $ZrO_2$ are presented.

TELFORD, R. E. See abs. 59.

TEMPLE, L. A. See abs. 398.

TERRY, G. See abs. 473.

THEW, K. See abs. 807.

781. **THIELKE, N. R., AND HENRY, E. C.** Refractory Materials for Use in High-Temperature Areas of Aircraft. Summary Report. Pennsylvania State Coll., AF-TR-6080, July 1950, 47 pp.

Data obtained during the program of research on refractories of aircraft purposes are treated according to the classification of the materials in systems of 1, 2, 3, or more components, comprising oxides, carbides, or metallic interaction products. More than 125 compositions in all systems were examined for mode of optimum preparation, thermal stability, melting behavior, crystallographic transformations, and porosity. Carbides and nitrides were investigated also for resistance to oxidation. The criterion of thermal-expansion behavior was applied wherever possible as a means of screening out those materials that were obviously of little value in preparation of bodies resistant to thermal shock. Actual testing to failure at various quenching temperatures supported expansivity data in many instances. Systems embodying aluminum titanate, zircon, mullite, and beryl, and their derivatives, were treated in considerable detail, in consequence of their appraisal as potentially valuable body compositions. Critical conclusions regarding observed facts and trends are presented, and recommendations are submitted for further research of a physical-chemical nature in the field of shock-resistant refractory materials and in the principles underlying these functions.

782. **THOMAS, C. L.** Reactions of Hydrocarbons in the Presence of Cracking Catalysts, Polymerization of Gaseous Olefins. Ind. Eng. Chem., vol. 37, No. 6, June 1945, pp. 543-545.

Synthetic silica-alumina catalysts, as prepared for catalytic cracking, will polymerize propylene and the butylenes. Synthetic silica-zirconia catalysts will polymerize butylenes. The three-component, synthetic cracking catalysts, silica-zirconia-alumina and silica-alumina-thoria, are active for polymerizing butylenes. The polymers in all cases are liquids boiling mostly within the gasoline range. A $C_8$ fraction, when hydrogenated, had an octane number of 95.3.

**THOMSON, S. J.** See abs. 175.

783. **THORNTON, W. M., JR., AND HAUBER, E. S.** Zirconium as a Material for Fractional Weights. Jour. Franklin Inst., vol. 250, No. 1, July 1950, pp. 39-44.

Apart from the concordant numbers for the composite-value signa (100 mg.) zirconium, which imply a satisfactory permanence on the part of the fractional weights of zirconium, the calibration data for the individual pieces are in agreement to the nearest microgram. Moreover, the smallness of the residuals and the accurate control determinations on the standard centigram (S 10 mg.) point to the probability that the experimental results are accurate.

784. **THRING, W.** Potential Uses of Super-Refractories. Research, vol. 7, No. 2, February 1954, pp. 54-59.

Discusses some of the potential uses of superrefractories or materials of modified properties and indicates the extent to which high-temperature research and development is dependent on the available materials, primarily oxides of silicon, aluminum, zirconium, and chromium.

**TINKLEPAUGH, J.** See abs. 249, 539.

**TOMBAUGH, R. W.** See abs. 304.

**TOWNES, C. H.** See abs. 693.

785. **TRAILL, R. J.** Preliminary Account of the Mineralogy of Radioactive Conglomerates in the Blind River Region, Ontario. Canadian Min. Jour., vol. 75, No. 4, April 1954, pp. 63-68.

Discusses the results of preliminary mineralogical studies in specimens from four occurrences in the area and includes a brief summary of the history and general geology of the discoveries. Radioactive conglomerates were discovered in the Blind River Region in the summer of 1953.

**TRIPP, H. P.** See abs. 740.

786. **TULL, R.** Zirconium Additions to Steel and Cast Iron. Heat Treat. and Forg., vol. 18, August 1932, pp. 471-473.

Discusses the use of zirconium in steel and cast iron and its effect upon the properties of castings.

**TURLEY, H. G.** See abs. 753, 754.

**TURLEY, H. G., AND SOMERVILLE, I. C.** Zirconium Tannage. II. Development of the Zirconium Tannage for White Leathers. See abs. 752.

787. **TYLER, P. M.** Hafnium. Bureau of Mines Inf. Circ. 6457, 1931, 11 pp.

Outlines the history, occurrence, analysis, geographical distribution, properties, separation of zirconium and hafnium and hafnium and zirconium, preparation, and productions.

788. **TYLER, P. M.** Rare and Minor Metals. Military Govt., Germany, Field Inf. Agency, FIAT Final Rept. 750, PB-28908, Mar. 1, 1946, 17 pp.

Reviews previous reports briefly and adds new information on wartime developments and novel production methods on rare and minor metals, including zirconium. Names German producers of 30 elements, and gives data on uses, prices, and quantities produced.

**TYREE, S. Y., JR.** See abs. 377.

### U

**ULRICH, A.** See abs. 773.

789. **URBAIN, G.** Should the Element of the Atomic Number 72 be Called Celtium or Hafnium? Chem. and Ind., vol. 42, Aug. 10, 1923, pp. 764-769.

Gives details of the experiments that lead to the discovery of hafnium, termed "celtium" in 1911

790. **USPENSKAYA, T. A., AND CHERNIKHOV, J. A.** Application of the Iodate Method to the Separation and Determination of Rare Elements. Compt. rend. acad. sci. U. R. S. S., vol. 28, No. 9, 1940, pp. 800-801.

Iodate is widely used as an oxidizing agent in chemical analysis. It has been successfully applied in a method of determining zirconium analogously to cerium and thorium. This method abuts on changing the iodate precipitate into zirconium oxide. The authors were also successful in producing a zirconium iodate of constant composition having the following empiric formula: $2\ Zr(IO_3)_4KIO_3.8H_2O$.

### V

**VALVEKAR, R. K.** See abs. 394.

**van ALPHEN, P. M.** See abs. 186.

**van AMSTEL, J. J. A. P.** See abs. 129.

791. **VENABLE, F. P., AND GILES, L. V.** Zirconyl Basic Chromate. Jour. Am. Chem. Soc., vol. 40, 1918, pp. 1653-1656.

Gives method for obtaining a definite, basic zirconium chromate by diluting and boiling solutions of zirconium hydroxide in chromic acid, to which the formula $2ZrO(OH)_2.ZrO.CrO_4.8H_2O$ may be assigned.

792. **VENKATESWARLU, C., AND RAO, B. S. V. R.** Zirconium: Its Estimation and Separation, Hydrazine Sulfate. Jour. Indian Chem. Soc., vol. 27, No. 8, 1950, pp. 395-396.

Hydrazine sulfate precipitates zirconium completely from solutions of PH 2.8 and above. This reagent also separates the element from beryllium, nickel, and rare earths in the PH range 2.8 to 3.0 in a single precipitation. Separation from thorium is more delicate, and the PH is critical at 2.8.

793. **VERMILYEA, D. A.** Electron and Photocurrents in Thin Films of $ZrO_2$. Acta Met., vol. 2, March 1954, pp. 346-348.

Presents a theory on variations of current flow through thin films of anodic $ZrO_2$ under the influence of temperature and field changes. Proposes that conductivity is facilitated by the presence of electron traps in the film and that the depth of these traps is diminished by an applied field. The equation relating field and temperature to conductivity is as follows:

$$\sigma = \sigma_\circ \exp\left[\frac{e^3E}{K}\ {}^{1/2} \Big/ kt\right]$$

where $\sigma_\circ$ is the conductivity in absence of a field. The defect structure of anodic $ZrO_2$ deduced from the experimental data is a semiconductor with a very small number of fairly deep traps. The theory and equations explained in this paper are shown to agree better with experiment than those suggested earlier by A. Charlesby (Acta Met., vol. 1, 1953, p. 348).

794. VERWEY, E. J. W., AND BUGEL, R. D. Ceramic Materials With a High Dielectric Constant. Philips Tech. Rev., vol. 10, No. 8, 1949, pp. 231-238.

Reports an investigation of the dielectric constants and dielectric losses of $TiO_2$ ceramic materials. Use of $ZrO_2$ in various mixtures is discussed. Describes a series of capacitors of small dimensions with a ceramic dielectric as used in radio receivers and other equipment incorporating high-frequency circuits.

795. VIANEY, L. R. Thermal Conductivity of 347 Stainless Steel and Zirconium. Massachusetts Inst. Technol., NP-1989, Feb. 15, 1951, 6 pp.

The thermal conductivities of 1-inch-diameter 347 stainless-steel and 0.626-inch-diameter crystal-bar zirconium rods, 1 foot in length, have been measured. Heat transferred along the axis was absorbed in a $H_2O$ calorimeter at the end, and the temperature gradient was measured by thermocouples at 3-inch intervals. All data obtained are tabulated and plotted (TID-3010).

796. VIGGERS, R. F. Magnesium-Zirconium Alloys. Oregon State Coll. (Thesis), June 1950, 42 pp.

Magnesium-zirconium alloys were prepared by three methods to discover the most promising alloying technique: (1) Compacts of zirconium-hydride powder and magnesium turnings were fused in a vacuum furnace. (2) Compacts of zirconium turnings and magnesium turnings were fused in steel bombs. (3) The proportion of zirconium in low-zirconium magnesium-zirconium alloys was raised by distilling away some of the magnesium. Mechanical segregation was found to be a major problem in alloys containing less than 35 percent zirconium. The temperatures used in alloying were limited by the boiling point of magnesium (1,100 C.). A series of alloys was made and subsequent metallographic, X-ray diffraction and microhardness led to the following conclusions: (1) At least 2 percent zirconium can be dissolved by magnesium. (2) Magnesium breaks up massive zirconium into small globules, without forming a eutectic, which was interpreted by the author as indicative of a peritectic reaction. (3) No phases other than alpha magnesium and alpha zirconium were found in the alloys.

797. VLAMIS, J., AND PEARSON, G. A. Absorption of Radioactive Zirconium and Niobium by Plant Roots From Soils and Its Theoretical Significance. Science, vol. 111, Feb. 3, 1950, pp. 112-113.

Insofar as the absorption of radioactive zirconium and niobium (columbium) is concerned, the $CO_2$-soil solution theory does not offer a satisfactory explanation. The only possible mechanisms are offered by the contact theory or by a soil-solution theory postulating the excretion of organic acids by plant roots or microorganisms growing in the same environment.

VLANNES, P. N. See abs. 448.

VOGE, H. H. See abs. 309, 310.

798. VOIGT, A. F. Progress Report in Radiochemistry, Nov. 1, 1949, to Apr. 30, 1950. Ames Lab., Iowa State Coll., ISC-110, June 15, 1950, 21 pp.

A detailed study of the zirconium-chloranilate complexes has been made. The work covered finding the zirconium: acid ratios, the stability constants, and the acid constants of the reagent itself (TID-3010).

799. VOIGT, A. F., SLEIGHT, N. R., HEIN, R. E., AND WRIGHT, J. M. Tracer Study of the Valence States of Neptunium. Argonne Nat. Lab., AECD-2575, ANL-JJK-19B-64, undated, decl. Apr. 20, 1949, 14 pp.

Studies of carrying neptunium tracer on zirconium phenylarsonate in the presence of various oxidizing and reducing agents. The precipitate, which is quite specific for even-valent ions, particularly quadrivalent ones, carries neptunium better from reducing solutions than from oxidizing solutions. The evidence can best be met by a proposal that the two lower valences stable in solution are IV and V. Duplicate experiments with plutonium tracer bear this out, since the behavior of plutonium is quite different from that of neptunium. Extraction methods tried for determining the valences were quite unsatisfactory.

VOOGD, J. See abs. 187.

W

800. **WAGGAMAN, W. H., AND GEE, E. A.** Titanium and Zirconium. Federal Sci. Prog., vol. 1, No. 5, 1947, pp. 18-19.

An elementary account of the properties, sources, and extraction of titanium and zirconium.

**WAGNER, B. F.** See abs. 225, 226.

**WAGNER, R. B.** See abs. 292, 293, 294, 295.

801. **WAINER. E.** Technology of Zirconium and Titanium and Their Compounds. Ceram. Age, vol. 48, November 1946, pp. 198-201, 215-216.

Summarizes the role of zirconium and titanium in industry and particularly in the ceramic field. Discusses occurrences, preparation, and properties of the important minerals zircon, silicate, and baddeleyite, as well as commercial applications of zirconium.

See also abs. 766.

**WALKER, L. J.** See abs. 297.

**WALL, N. S.** See abs. 300.

**WALLACE, H., JR.** See abs. 705.

**WALLACE, R. H.** See abs. 802.

802. **WALLACE, W. P., AND WALLACE, R. H.** Endurance Limit of Zirconium. Iron Age, vol. 173, No. 11, Mar. 18, 1954, pp. 146-147; Metal Prog., vol. 65, No. 4, April 1954, pp. 128, 130.

Many properties of zirconium and its alloys have been thoroughly investigated, but little is known of their fatigue properties. To gain more information, so that parts made of these alloys may have longer service life and serve more efficiently, the Livermore Research Laboratory tested specimens of crystal-bar zirconium under repeated stress at room temperature. Results show that zirconium does not have a clearly defined endurance limit.

803. **WALLBAUM, H. J.** (Systems of Metals of the Iron Group With Titanium, Zirconium, Columbium, and Tantalum). Arch. Eisenhüttenw., vol. 14, No. 10, 1940-1941, pp. 521-526.

X-ray and metallographic analyses are presented on the binary systems of iron, manganese, nickel, and cobalt with titanium, zirconium, columbium (niobium) and tantalum. In the iron-zirconium, cobalt-chromium, and cobalt-tantalum systems there has been established in the presence of an excess of about 7 atom-percent of iron or cobalt, an additional Laves phase, the eta compound. It crystallizes in accordance with the following peritectic reaction: Liquid phase + epsilon phase = eta phase.

**WALSTED, J. P.** See abs. 466.

**WALTON, R. B.** See abs. 605.

**WANG, P.** See abs. 474.

804. **WAPSTRA, A. H., AND JONGEJANS, C.** Decay of $^{173}$ Hafnium. Physica, vol. 20, No. 1, 1954, p. 36.

A brief note on the decay of hafnium.

**WARDLAW, W.** See abs. 93, 94, 95, 96, 97, 98, 99.

805. **WARDLAW, W., AND BRADLEY, D. C.** Zirconium Esters. Nature, vol. 165, No. 4185, Jan. 14, 1950, pp. 75-76.

Discusses preparation of ortho-esters of zirconium.

**WARING, C. L.** See abs. 475.

**WARNER, J. C.** See abs. 672.

806. **WARSHAW, S. D.** Note on the Preparation of Uniform Metallic Foils. Rev. Sci. Instruments, vol. 20, 1949, pp. 622-623.

Gives a method for the preparation of metallic foils of uniform thickness, free of wrinkles and pinholes.

**WATERHOUSE, E. F.** See abs. 696.

**WATSON, W. W.** See abs. 159.

**WATT, L. M.** See abs. 573.

**WATT, W.** See abs. 329.

807. **WAY, K., FANO, L., SCOTT, M. R., AND THEW, K.** Nuclear Data. Nat. Bureau of Standards Circ. 499, Sept. 1, 1950, pp. 21, 96-98.

Tabulated nuclear data on zirconium, niobium, and molybdenum.

808. **WEAVER, B.** Separation Factor - a Criterion for Evaluation of Fractional Separation Processes. Oak Ridge Nat. Lab., ORNL-1627, Nov. 10, 1953, 10 pp.

Results of research on fractional separation of a pair of similar elements show that more use should be made of the "separation factor" as a criterion for determining the effectiveness of a single stage in a division of a mixture into two fractions. The "separation factor" is the ratio between two elements in one fraction divided by their ratio in the other fraction. It is independent of the original composition and of the extent of the separation process. The literature dealing with separation of the hafnium-zirconium pair and the rare-earth group has been surveyed as a means of evaluating separation methods. Separation factors have been calculated and compiled from the small amount of useful data. This criterion has been applied usefully in development of a separation process.

**WEBER, C. E.** See abs. 257.

**WEBSTER, H. B.** See abs. 469.

809. **WEDOW, H., JR., AND KILEEN, P. L.** Reconnaissance for Radioactive Deposits in Eastern Interior Alaska, 1946. U. S. Geol. Survey Circ. 331, 1954, 36 pp.

Reconnaissance in 1946 in the Tanana and upper Copper River valleys initiated field radioactivity tests in eastern interior Alaska. Although this reconnaissance did not yield further information on the source of the few concentrates of higher radioactivity that had been obtained previously, a few new sites of radioactivity were found. Data for all sites are presented. The slight radioactivity of the igneous rocks appears to be due to traces of uranium and thorium in such accessory minerals as zircon and allanite.

810. **WEINTRAUB, A. A.** Flaming Metal. Safety Eng., vol. 99, No. 3, March 1950, pp. 34, 35, 47, 48; vol. 99, No. 4, April 1950, pp. 29, 40-42.

Outlines the relative dangers of the various metals, warns safety engineers against hazardous metal conditions, and offers rules for preventing metal-dust fires and explosions.

811. **WEISER, H. B., AND MILLIGAN, W. O.** Constitution of Inorganic Gels. Advances in Colloid Sci., vol. 1, 1942, pp. 227-246.

Summarizes results of investigations concerning the constitution of oxide and salt gels, using the phase rule and diffraction technique.

812. WEISER, H. B., AND MILLIGAN, W. O. Zones of Mutual Protection Against Crystallization in Dual-Oxide Systems. Jour. Phys. and Colloid Chem., vol. 52, 1948, pp. 942-949.

Mutual protective action has been observed in the following dual-oxide systems heated for 2 hours at 565° C.: BeO-Al$_2$O$_3$, ZrO-Al$_2$O$_3$, and SnO$_2$-Al$_2$O$_3$. Pure zironia gel is usually monoclinic at a temperature level of 500°-600° C., but the tetragonal form is stabilized by 10 mole-percent of alumina. Larger amounts of alumina render the zirconia amorphous to X-rays.

813. WELCH, A. J. E., ANDERSON, J. W., AND CHATT, J. Inorganic Chemistry of Some Metallurgical Processes. Ann. Rept. Prog. Chem., Chem. Soc. (London), vol. 43, 1947, pp. 129-137.

Reviews the extraction of magnesium (particularly sea water), the production of highly electropositive metals by thermal reduction processes, the extraction of alumina and aluminum from clay, and the extraction chemistry of beryllium and zirconium.

WELLER, C. V. See abs. 360.

814. WENNING, W. F. Zirconia in Sheet Iron Enamels. Bull. Am. Ceram. Soc., vol. 2, 1923, pp. 102-104; Jour. Soc. Glass Tech., vol. 7, 1923, p. 241.

Investigation and research show the value of zirconia as an opacifying agent. Enamels containing zirconia are more resistant to mechanical and thermal shock; they are more acid resistant, and the zirconia in these enamels is not affected by reducing furnace heat.

WEST, J. B. See abs. 79.

WEST, R. See abs. 539.

815. WEST, T. S. Analysis for Industry. Ind. Chem., vol. 30, No. 358, November 1954, pp. 550-552.

Gives a method for the extraction of niobium (columbium) from zirconium by a solvent-extraction procedure, employing a mixture of butyl phosphoric acids in butyl ether as the extracting solvent.

816. ___. Separation Methods in Metallurgical Analysis. Metallurgia, vol. 43, No. 255, January 1951, pp. 41-46.

Developments are continually taking place with a view to the more efficient separation of various metals in metallurgical analysis. A review of recent progress in extraction and precipitation methods is presented.

817. WESTERN INDUSTRY. What's Ahead for the Metals and Metalworking Industries of the West. Vol. 19, No. 3, March 1954, pp. 54, 55, 57.

A field survey of the outlook for metals, including zirconium and metal working in the West.

WHEELER, C. M., JR. See abs. 324.

WHITE, C. E. See abs. 167, 313.

WHITE, G. D. See abs. 713.

WHITE, H. E. See abs. 283.

WHITE, J. C. See abs. 517.

WHITE, M. R. See abs. 706, 707, 708.

818. WHITE, M. R., AND SCHUBERT, J. Action of Salts of Zirconium and Other Metals on Plutonium and Yttrium Distribution and Excretion. Jour. Pharmacol. and Exptl. Therap., vol. 104, March 1950, pp. 317-324.

Treatment of rats with zirconium prior to injection of plutonium (Pu$^{239}$) and yttrium (Y$^{91}$) lowered the amount of plutonium and yttrium subsequently deposited in the skeleton and increased the amount of plutonium in the kidneys. The deposition of both plutonium and yttrium in the bone was correlated with the length of time between pretreatment and their injection. Zirconium injected 24 hours after plutonium and yttrium prevented further deposition of the radioelements in bone, but had no other observable effect on their organ distribution. In addition to zirconium other hydrolyzable elements, manganese, iron, titanium, aluminum, and thorium, reduced bone deposition of plutonium but had various effects on the amounts deposited in other organs. Aluminum and thorium increased the plutonium content of the liver and other soft tissues. Nonhydrolyzable magnesium had no significant effect on the distribution of either plutonium or yttrium. The mechanism by which salts of zirconium and other hydrolyzable elements may affect plutonium and yttrium metabolism is discussed. This included adsorption of the radioelement on colloidal aggregated in the circulation and the relation between particle size and the resulting distribution of the aggregate plus adsorbed radioelement.

819. WHITTEMORE, O. J., JR. Pure Oxide Heavy Refractories. Chem. Eng. Prog., vol. 44, No. 11, November 1948, pp. 872-874.

Properties of new pure-oxide heavy refractories of alumina, magnesia, and stabilized zirconia were determined. These properties indicate that refractories of this type can be used to line industrial furnaces so that operation at very high temperatures can be effected. Stabilized zirconia refractories were shown to have lower thermal conductivity than fireclay brick despite their being twice the bulk density. Pure alumina refractories having either high or low thermal conductivity were capable of withstanding temperatures up to 1,900° C. Magnesia refractories were tested that have high conductivity and excellent high-temperature load-bearing capacity.

820. WICHMANN, A. P. Progress and Trends in Metal Production. Mines Mag., vol. 44, No. 4, April 1954, pp. 25-28.

This report analyzes problems facing the extractive metallurgist and reviews progress in the production of metals, including zirconium.

821. WILCOX, R. Occurrence of Large Zircon Needles in a Basic Pegmatite. Am. Mineral., vol. 21, 1936, p. 459.

Crystals of zircon up to 7-1/4 inches in length and 1/16 to 1/8 inch in diameter occur in a basic pegmatite near Mellen, Wis. The pegmatite, which is about 1-1/2 feet wide, cuts the gabbro country rock. It contains large crystals of basic plagioclase, hornblende, and biotite, penetrated by the needles of zircon. The zircon is nonmagnetic, has a specific gravity greater than three, and shows prismatic parting. Its color is cinnamon brown with adamantine lustre. The crystals are uniaxial and positive and show parallel extinction. The refractive index of the ordinary ray is 1.925 + 0.002, and the birefringence determined on thin sections of grains with the universal stage is 0.054 + 0.0002. An X-ray powder photograph by George W. Field of the University of Wisconsin shows a typical zircon pattern.

822. WILCOX, R. J. Metal Penetration Decreased by Use of Zircon Sands. Am. Foundryman, vol. 25, No. 3, March 1954, p. 78.

Concerns the use of special molding refractories, such as zircon sand in areas particularly susceptible to metal penetration.

823. WILD, G. O. Zircon - No Longer A Gem of Mystery. The Mineral., vol. 15, No. 7, July 1947, pp. 339-345.

Discusses normal zircon, fully crystallized stones of the gem variety, in which the color may range from colorless through orange-red and blue, its occurrence, properties, chemical treatment, and cutting.

824. WILDER, D. R., AND FITZSIMMONS, E. S. Stability of Zirconium Oxide in Graphite Surroundings. Ames Lab.,

Iowa State Coll., ISC-403, Sept. 1, 1953, 15 pp.

Zirconium oxide specimens that have been fired at high temperatures in graphite enclosures are known to fail mechanically upon oxidation; a review of the literature failed to completely explain such failure. Possible causes of failure arising both from internal and external influences, are discussed. Experimental investigation established the presence of zirconium carbide in all specimens where failure later occurred. Compressive strengths were measured both before and after oxidation and are discussed. Limitations and recommendations for graphite firing of zirconium oxide are given.

WILDER, M. P. See abs. 242.

WILHELM, H. A. See abs. 79, 679.

WILHELM, J. O. See abs. 538.

825. WILKINSON, G., AND BIRMINGHAM, J. M. Bis-Cyclopentadienyl Compounds of Titanium, Zirconium, Vanadium, Niobium, and Tantalum. Jour. Am. Chem. Soc., vol. 76, No. 17, Sept. 5, 1954, pp. 4281-4284.

Bis-cyclopentadienyl halides of titanium, zirconium, and vanadium in the IV oxidation state and of niobium and tantalum in the V oxidation state have been prepared by the reaction of the anhydrous metal halides with cyclopentadienylmagnesium halides or with cyclopentadienylsodium. The properties of the halides are given, and the preparation of the ions $(C_5H_5)_2$ titanium + and $(C_5H_5)_2V^+$ by reduction of the IV valent titanium and vanadium compounds in aqueous solution is described. The electronic structure of the derivatives is discussed briefly.

826. WILKINSON, G., AND HICKS, H. G. Radioactive Isotopes of the Rare Earth Elements. III. Lutecium Isotopes and Hafnium Isotopes. Radiation Lab., Univ. California, UCRL-429, Aug. 30, 1949, 21 pp.

A study has been made of radioactive isotopes of lutecium and hafnium, produced by bombardments of thulium and ytterbium with 38, 31, and 19 Mev. alpha-particles, of lutecium and hafnium with 19 Mev. deuterons, and of tantalum with 190 Mev. deuterons.

WILLBANKS, O. L., JR. See abs. 321.

827. WILLIAMS, A. E. Silester Bonding Process. Ceramics, vol. 2, 1950, pp. 532-534.

Gives details of the silester bonding process for the syntheses of silicates such as mullite $3Al_2O_3.2SiO_2$, forsterite $2MgO.SiO_2$, and zircon $ZrSiO_4$ from high-quality sillimanite, alumina, magnesia, and zirconia. These materials form the basis of a new group of refractory materials, which are finding useful applications for high-temperature work in a number of different industries.

828. WILLIAMS, A. E. Zirconium: Its Use in Magnesium Alloys. Min. Mag., vol. 88, No. 5, May 1953, pp. 273-276.

Discusses the grain-refining effect of zirconium on magnesium and alloy properties.

WILLIAMS, G. C. See abs. 48.

829. WILLIAMS, J. T. Vanadium-Zirconium Alloy System. Ames. Lab., Iowa State Coll. ISC-491, June 15, 1954, 32 pp.

The equilibria in the vanadium-zirconium alloy system were investigated by solidus-temperature determinations, thermal analysis, dilatometry, electrical resistance measurements, microscopic examination, and X-ray diffraction analysis. A eutectic reaction occurs at 1,230° C. between a compound, $V_2Zr$, and a solid solution containing 10 percent vanadium in beta zirconium. $V_2Zr$ decomposes at 1,300° C. into liquid, and a solid solution containing about 10 percent zirconium in vanadium. The eutectic composition is probably about 30 percent vanadium. A eutectoid reaction between $V_2Zr$ and alpha zirconium takes place at

777° C. at a very high rate. The eutectoid composition is 5 weight-percent vanadium. The limit of solubility of zirconium in vanadium was estimated to be 5 percent at 600° C. No attempt was made to determine the liquidus for the system.

830. WILLIAMS, W. L. Corrosion of Titanium and Zirconium. U. S. Naval Eng. Exp. Sta., NP-3453, May 14, 1951, 16 pp.

Results of corrosion tests in a seacoast atmosphere, in quiet sea water (fouling conditions), and in slowly moving sea water, covering the long-tenure tests incomplete at the time of the last report. Data are also presented on the high-velocity sea water resistance of new titanium and titanium-alloy materials, including heliarc-welded titanium. Brief stress-corrosion tests of zirconium in brackish water are also included.

WILSON, D. W. See abs. 156.

WINTERSON, W. G. See abs. 446.

WITHROW, J. R. See abs. 157.

WOLLAN, E. O. See abs. 676.

831. WOOD, F. W., BORG, J. O., AND BEALL, R. A. Arc Ingot Conditioning by Sidewall Fusion. Bureau of Mines Rept. of Investigations 5149, 1955, 11 pp.

Ingots of zirconium and other highly reactive metals, such as titanium and hafnium, produced by the consumable-electrode arc-melting process require conditioning before forging or rolling. A nondestructive, arc-conditioning technique has been developed as a substitute for lathe conditioning. The technique employs an electric arc under an inert atmosphere to fuse surface metal on the sidewalls of ingots without seriously affecting the general quality of the ingots. Advantages of the practice are increased yields lower accumulation of inferior scrap, and actual cost savings. The work cited in this report was done on zirconium.

WOODRUFF, S. A. See abs. 3.

WOOLF, A. A. See abs. 238.

832. WORNER, H. W. Production and Utilization of Titanium and Zirconium. Australasian Eng., vol. 45, July 7, 1953, pp. 46-51.

Outlines current methods of extracting titanium and zirconium from their minerals. Describes techniques of melting and fabrication; draws attention to the more unusual aspects of the technology of the metals. Discusses the outstanding properties of titanium-rich alloys and outlines the present and prospective uses of the materials. Briefly describes some properties and applications of zirconium.

833. ___. Titanium and Zirconium - New Metals in Australian Metallurgy. Chem. Eng. and Min. Rev., vol. 40, No. 7, Apr. 10, 1948, pp. 254-262.

A survey of ore supplies, production of the metal, properties, uses, and alloys.

WRIGHT, J. M. See abs. 799.

834. WRIGHT-PATTERSON AIR FORCE BASE (translation). (Zirconium). ATI-48527, December 1948, 34 pp. (Original author, publishing agency, dates unknown.)

Discusses the four main groups of zirconium ores, preparation of the pure metal, chemistry of zirconium, properties of zirconium metal, practical application of zirconium metal, zirconium with metalloids and the hard bodies, and zirconium in special steels. The main applications for zirconium are: As a main component in combination with carbon, boron, and nitrogen; possibly also a combination of these additions, and a combination of the same compounds of related metals as refractory and hard bodies; as an addition to steel with a refining and purifying effect; and zirconium oxide as a refractory material.

835. WROUGHTON, D., AND LILLIENDAHL, W. C. Removal of Gaseous Embrittlement From Zirconium, Progress Report. Westinghouse Elec. Corp., NYO-1014, Jan. 23, 1950, 2 pp.

A series of test samples were prepared by doping a Foote 1/8-inch-diameter rod with quantities of oxygen varying from about 0.05 to 0.30 percent by the oxidation and homogenizing procedure. The oxygen was removed by molten-calcium soaking. Samples that had been doped with spectroscopically pure nitrogen and treated in molten calcium were also analyzed.

## Y

YERKES, L. A. See abs. 463.

836. YOE, J. H. Third Symposium on Organic Analytical Reagents. Virginia Jour. Sci., vol. 3, No. 1, 1942, pp. 8-10.

The precipitation of zirconium by means of 5-chlorobromamine acid was studied in some detail. The reagent gives a voluminous, bright-red precipitate, but unfortunately no means was found for making the reaction quantitative. The reaction is, however, valuable as a qualitative test for zirconium. Similar studies were made with copper and again resulted in a nonquantitative precipitation of copper.

837. YOE, J. H., AND OVERHOLSER, L. G. Organic Analytical Reagent Studies: New Colorimetric Reagents for Silver, Copper, Cobalt, Zirconium and Phenothiazine. Virginia Jour. Sci., vol. 3, 1943, pp. 304-305.

Discusses five new colorimetric reactions that have been discovered and how these reactions have been made the bases for the colorimetric determination of zirconium, silver, copper, cobalt, and phenothiazine.

YOLLES, S. See abs. 377.

838. YOUNG, R. C., AND ARCH, A. Zirconium Acetylacetonate. (Ch. in Inorganic Synthesis, vol. 1, H. S. Booth.) McGraw-Hill Book Co., Inc., New York, N. Y., 1939, pp. 121-122.

Describes a procedure for the preparation of zirconium acetylacetonate.

839. YOUNGMAN, E. P. Zircon (The Gem). Bureau of Mines Inf. Circ. 6465, July 1931, 20 pp.

Discusses history, description, and properties in relation to zircon.

## Z

840. ZENO, R. S., and LESLIE, H. L. C. Inert Arc Welding of Thin Walled Tubing. Knolls Atomic Power Lab., AECU-1546, 1951, 21 pp.

Investigation to determine factors influencing the inert arc-welding of thin tubing. The use of $ZrO_2$-coated electrodes was found to give a more stable arc. Arc wander was minimized owing to the increased emissivity of the electrode (TID-3010).

841. ZEPPELIN, H. von. (Preparation of Zirconium Metal by Reduction of Zirconium Tetrachloride With Magnesium). Metall. u. Erz., vol. 40, 1943, pp. 252-254.

Study of a simplified process for producing zirconium from the chloride (37 percent zirconium, 1.5 iron, 0.3 aluminum) by chlorination of zirconium ore. Particulars are given on process development, and steps recommended for drying the resulting wet zirconium powder without explosion hazard.

842. ZIEBLAND, H. Review of the Current Techniques of Protecting and Cooling Rocket Motor Walls. Jour. British Interplanetary Soc., vol. 13, No. 3 May 1954, pp. 129-141.

Original from THE OHIO STATE UNIVERSITY

Describes the current techniques of protecting and cooling liquid-propellant rocket-motor walls. The underlying physical principles are explained for each case in an elementary way, and with the aid of diagrams, some of the advantages and shortcomings of each technique are pointed out.

843. ZIMMERMAN, W. F., PLANKEHORN, W. J., AND BENNETT, D. G. Aluminum Titanate as a Porous Insulating Material for the Protection of Metal. Univ. Illinois, WADC-TR-53-187, AD-14763, May 15, 1953, 17 pp.

Ceramic bodies composed of prereacted aluminum titanate and varied percentages of Florida kaolin, Tennessee No. 5 ball clay, Fulton plastic clay, or barium zirconium silicate were dry pressed into briquettes and fired at 2,700°, 2,800°, or 2,900° F. They were compared with respect to their physical properties, including firing shrinkage, modulus of rupture, apparent porosity, bulk density, and thermal expansion. Body AT 11, containing 60 percent aluminum titanate and 40 percent Florida kaolin had the best combination of physical properties important in the development of a refractory lightweight insulating material. Additions of either sawdust or charcoal, as a burnout agent, to body AT 11 resulted in the production of a lightweight insulating material having physical properties similar to those of commercial insulating materials but with the added feature of a lower coefficient of expansion.

844. ZINN, W. H. Two-Crystal Study of the Structure and Width of K X-Ray Absorption Limits. Phys. Rev., vol. 46, Oct. 15, 1934, pp. 659-664.

The double-crystal spectrometer has been used to examine the K absorption limits of the elements selenium, rubidium, zirconium, molybdenum, and compounds of these elements. All substances examined showed structure either on the short wavelength side of the main absorption limit or in the limit itself. The intensity and location are discussed with reference to the theory of secondary structure given by Kronig. The widths of the absorption limits have been measured, and it is shown that the widths are approximately constant for elements of atomic number less than 32, and that from there on they increase as the fourth power of the atomic number.

ZUCKER, E. R. See abs. 516.

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